ASTRONOMY

December 1984
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Race to the Moon: the Soviet Story

How to Get Great Schmidt Photos

Tuning into the Sun's Interior

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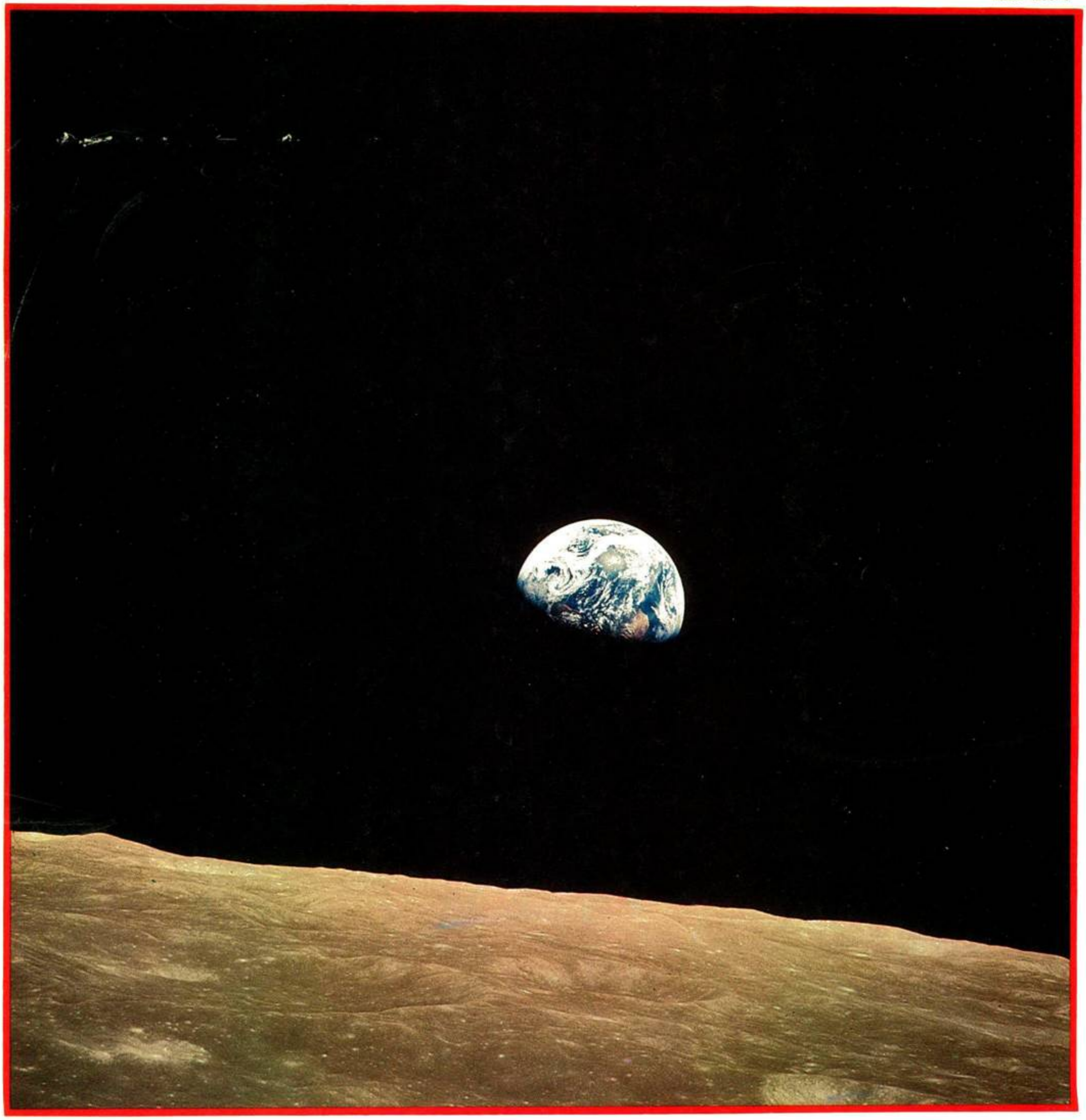
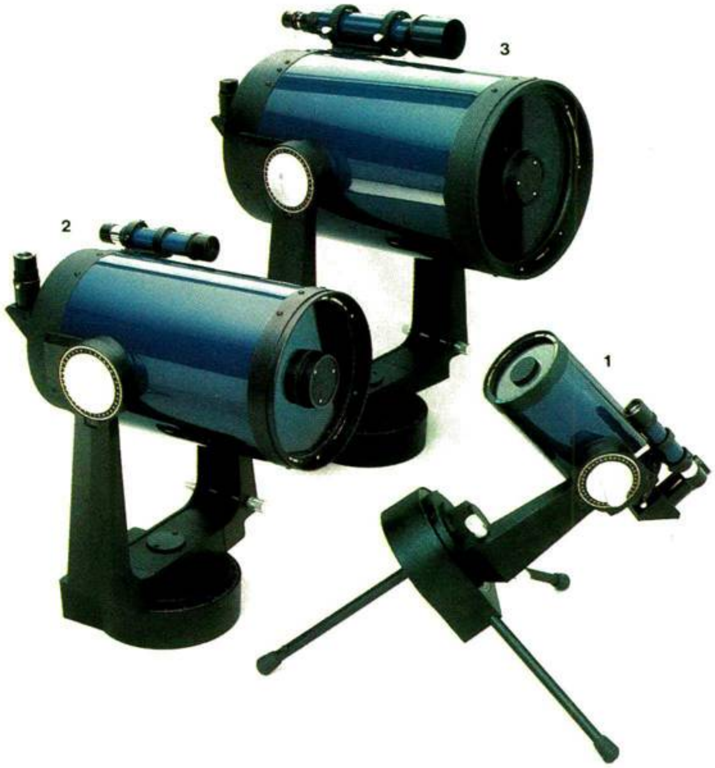
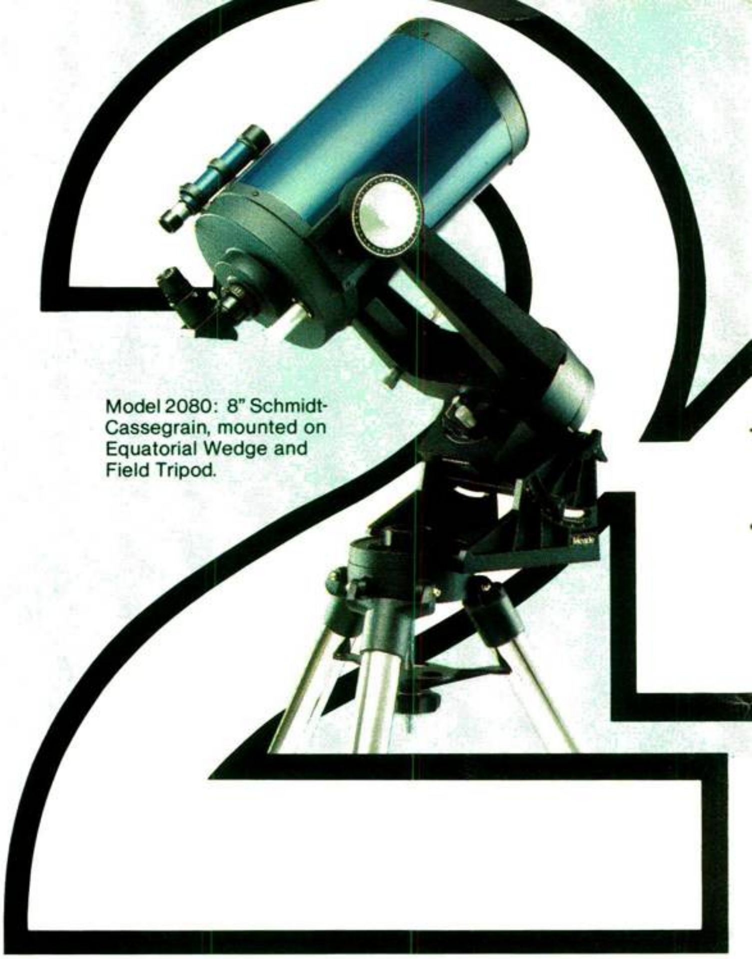


Earthrise over the Moon

Meade Schmidt-Cassegrain Telescopes: **(1)** 4" Model 2044, with standard-equipment table tripod; **(2)** 8" Model 2080; **(3)** 10" Model 2120.





Model 2080: 8" Schmidt-Cassegrain, mounted on Equatorial Wedge and Field Tripod.

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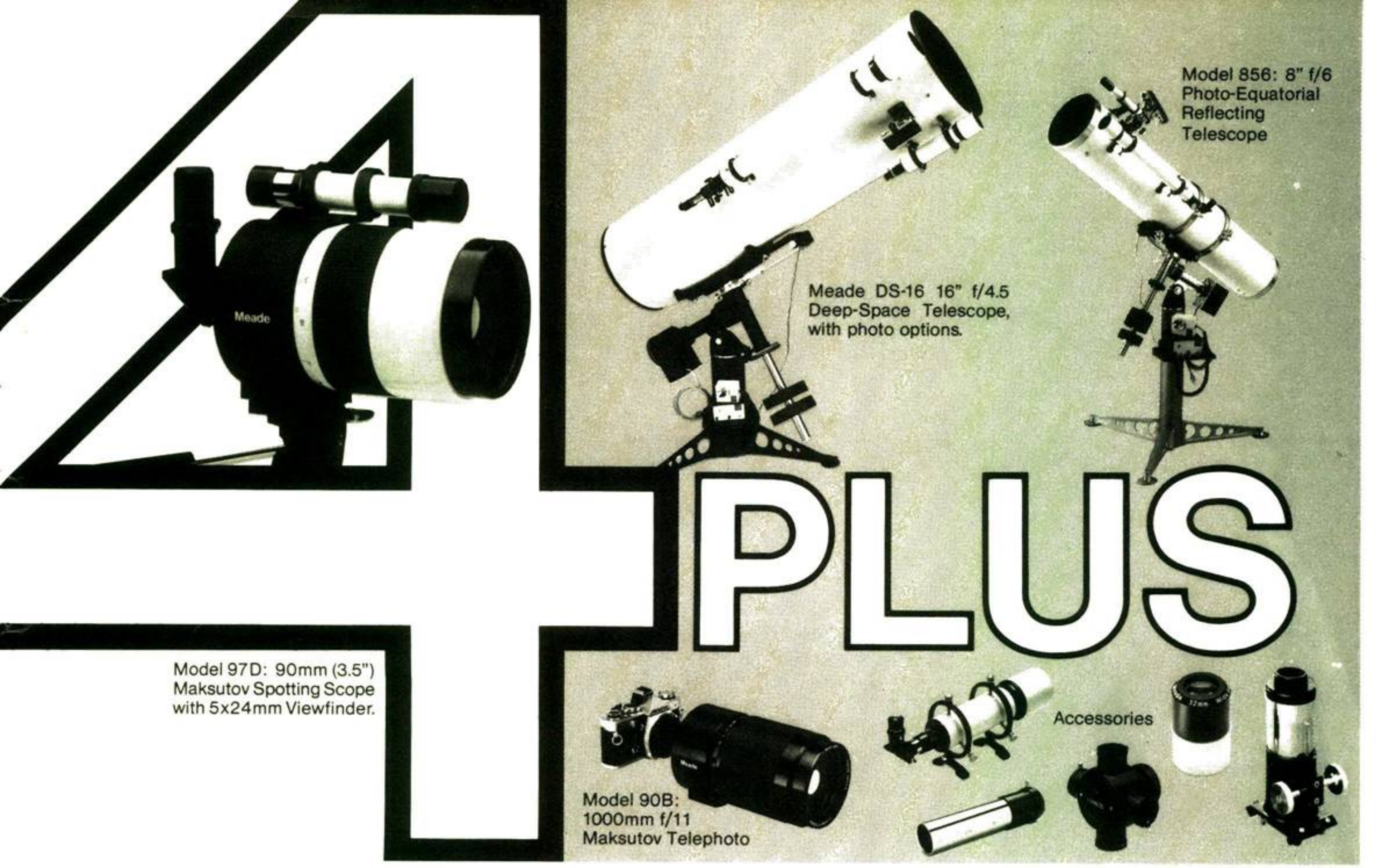

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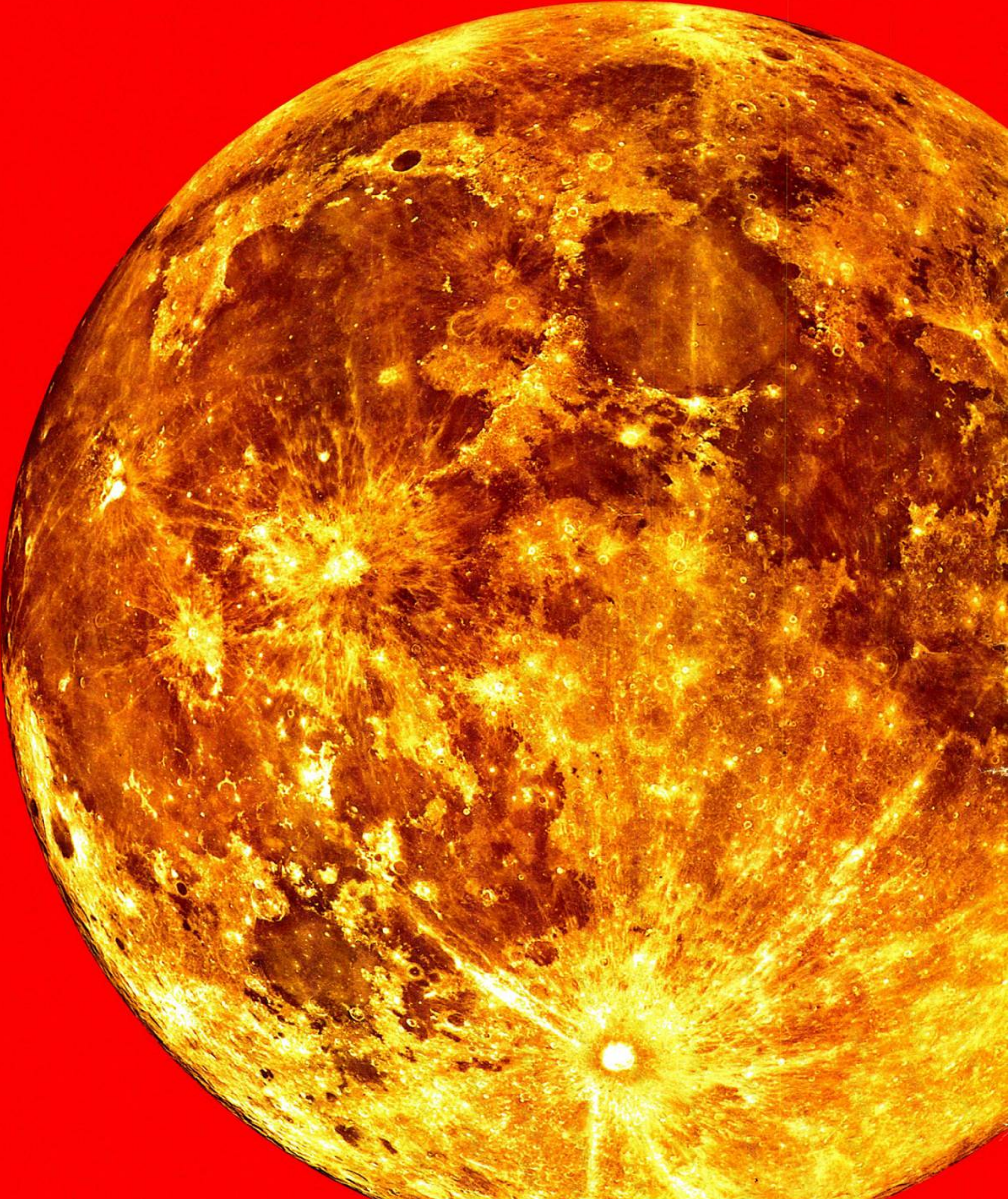

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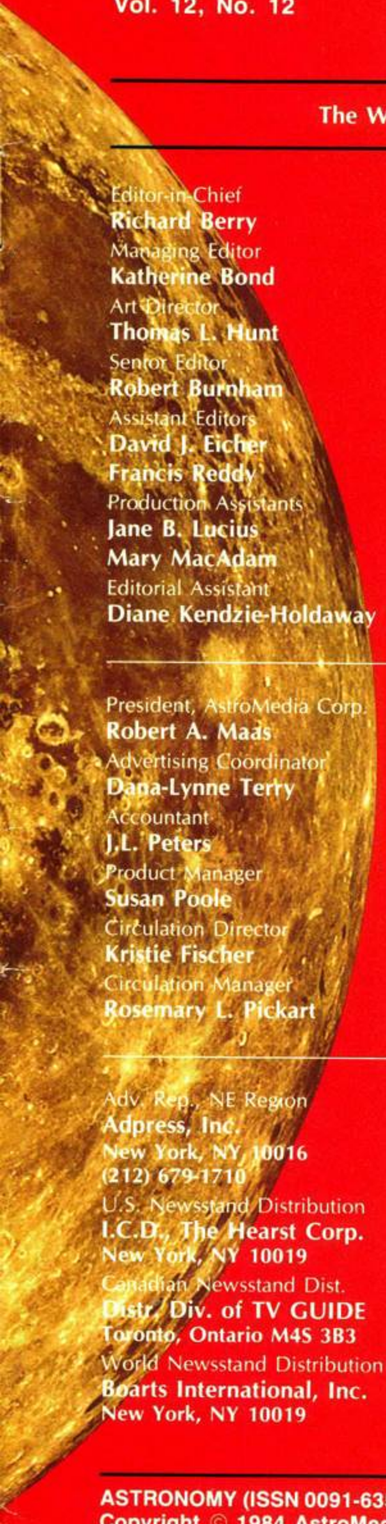

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Cover: The flight of Apollo 8 in December 1968 — the first manned mission to circumnavigate the Moon — gave America a decisive lead in the race to the Moon. Confronted with a stinging national defeat, the Soviets started proclaiming what many people still believe today — that they had never been competing with the Americans anyway. But what *really* happened? This month ASTRONOMY explores the history of the Moon race and reveals the secret story of the ill-fated Soviet lunar program. Cover photo from NASA; these pages, Lick Observatory.

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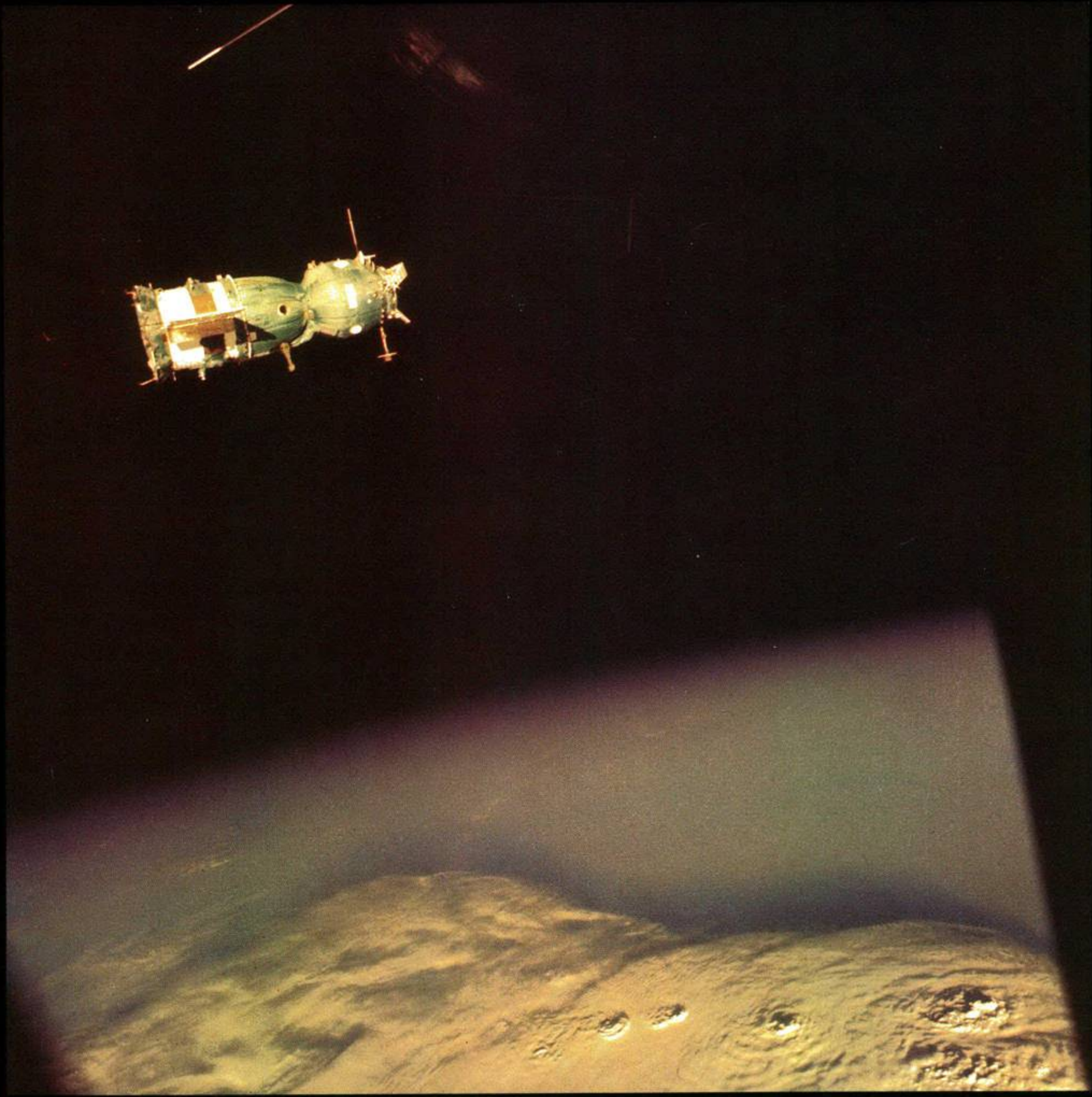
BOND

Soviets to the Moon: the Untold Story

by
Peter Pesavento

All paintings and artwork by Bruce Bond



Photographed from an American Apollo craft during the joint Soviet-American flight in 1975, Soyuz 19 floats in orbit over a cloud deck dotted with thunderheads. NASA photo.

Fifteen years ago last August, the Russian spacecraft Zond 7 circumnavigated the Moon with a solitary loop and on reentry into the Earth's atmosphere, executed a double-skip G-reducing maneuver. Twenty minutes later, it bumped down in the middle of a collective farm wheatfield south of the western Siberian city of Kustanai. This unmanned Moon shot drew little notice in the wake of Apollo 11's landing the month before. Coupled with Soviet statements that robot spacecraft "could explore the lunar environment at less cost and without risk to human life," Zond 7 wrote a bitter conclusion to the most enigmatic and controversial question in 25 years of space exploration: Were the Soviets racing the Americans to the Moon?

For most people, along with the western popular press, the answer was and still remains no. The Russians, they say, never had the technology or the willpower to execute such a feat. Others claim that the Soviets, with a clever propaganda campaign, hoodwinked the Americans into wasting $12 billion to "put some clown on the Moon," while the Kremlin instead funded a buildup of its military power.

But to Western analysts and observers of the Soviet space program, the answer is quite different. They claim the Russians *were* in a race and came very close to upstaging Apollo 11 with a lunar spectacular just 12 days before Armstrong, Aldrin, and Collins blasted off.

This difference of opinion points out an inherent problem with interpreting Russian space events. The difficulty is compounded by the Soviets themselves who characteristically announce project goals well in advance, but never detail the purpose of specific space missions or major advances in their program until they are achieved. Because of this, the Moon race between the superpowers will always be wrapped in a certain amount of controversy.

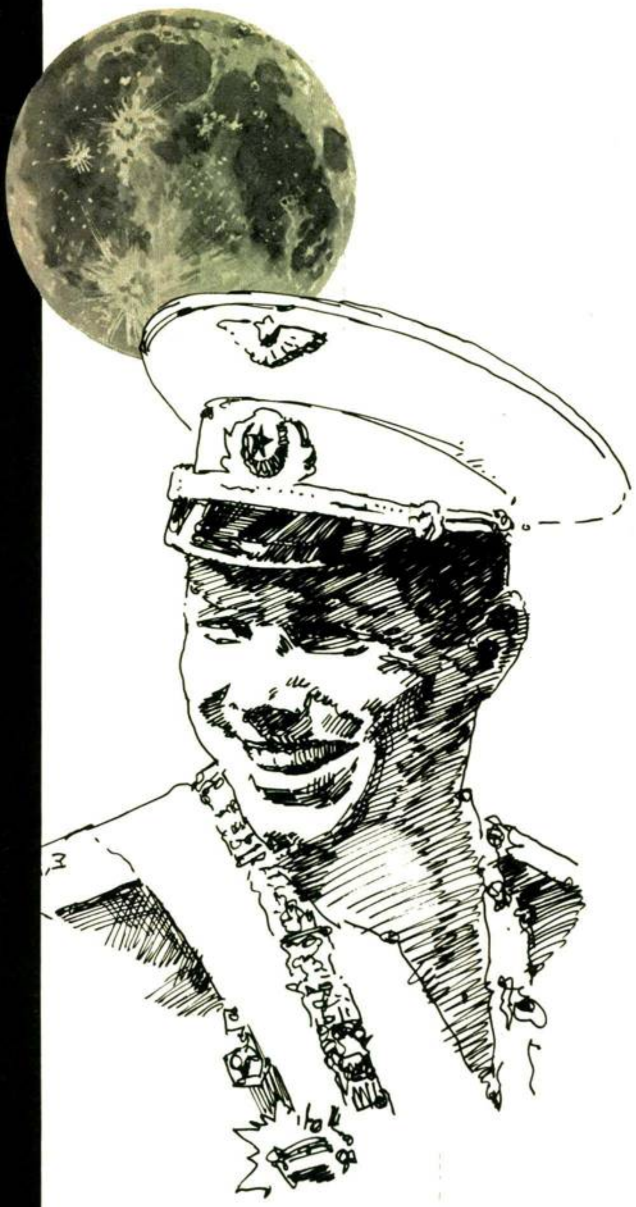
Media coverage has not always accurately portrayed the Soviet space program. Factual evidence reveals that by the early 1970s, the Russians had:

- built spacecraft and boosters that were only for manned flights to and from lunar orbit and the Moon's surface;
- trained a cadre of cosmonauts to operate in near-Moon space and upon the lunar surface;
- commissioned an ocean-going fleet of ships that could communicate with spacecraft in lunar orbit;
- publicized statements by officials and cosmonauts that accurately told of the U.S.S.R.'s space intentions.

The Soviet efforts to reach the Moon during the 1960s closely paralleled the American drive. Evidence points to a race that was nose to nose right down to the wire, with the Soviets faltering only at the finish line. It wasn't until the United States successfully put men on the lunar surface that the Russians began to deny that they had such aspirations.

Throughout the 1960s — right up to July 1969, in fact — Soviet space personalities stated their views and intentions regarding the Moon race. These comments, reflecting officially-approved ideas, received wide exposure in the Soviet- and satellite-controlled media. Cosmonauts, engineers, and members of the Soviet Academy of Sciences detailed where the U.S.S.R. stood relative to America in their goal to land men on the Moon. They were straightforward and candid:

In 1965, Pavel Belyayev (commander of the Voskhod 2 flight) boastingly told a Czech interviewer, "The



Yuri Gagarin:

The first man ever to fly in space and leading candidate for a Moon flight, Gagarin was killed in an airplane crash in early 1968.

Leonid Brezhnev: Reportedly political boss of the Soviet space program under Nikita Krushchev, Brezhnev was equally supportive of the program when he came to power in 1964.

Americans speak broadly about their preparations to land a man on the Moon, but naturally, we in our country are not idle, either. We shall see who will be first."

In 1966, Aleksei Leonov (the first space walker) informed a Hungarian journalist that Russian unmanned flights to the Moon would be followed by manned orbiters, which in turn would prepare the way for manned landings. He added: "I think I do not disclose any secret by saying Soviet cosmonauts are preparing for such a journey."

The following year Academician R. Orbastov said, "The very next milestone in our conquest of space will be manned circumnavigation of the Moon, and then a lunar landing."

In early 1968, rocket specialist Pokorny stated that the Russian approach was going to be more cautious than the American, using dogs in robot landers before men. But, "the manned landing should be accomplished before the end of 1970," he declared confidently.

These statements may have been mere gloating, because Soviet space efforts at that time were ahead of America's, but the following *nonpublic* examples corroborate the claims:

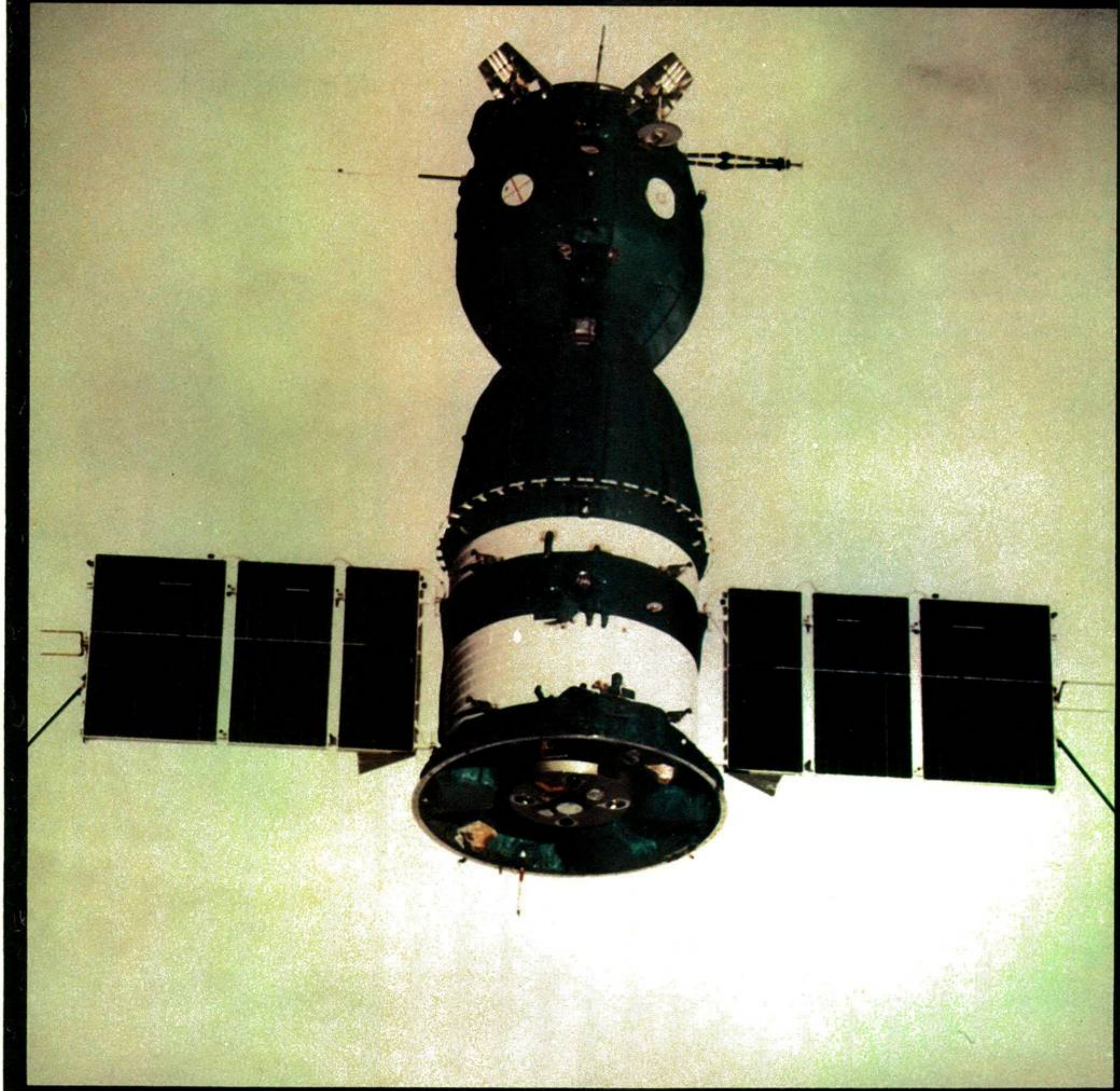
At the Paris Airshow in May 1967, Gemini astronauts Michael Collins and David Scott got acquainted with their Russian counterparts Konstantin Feoktistov and Pavel Belyayev. The four met several times during the show and at one off-the-record meeting recalled by Collins in his book *Carrying the Fire*, "We found that the Russians had a group of cosmonauts training in helicopters, and that Belyayev himself expected to make a circumlunar flight in the not-too-distant future." Scott confirmed Collins' record of the event.

Nikita Khrushchev, Soviet premier and political-mastermind of early space successes, wrote in his memoirs (widely believed in the West to be genuine) of planned Moon flights by cosmonauts. While reflecting on the death of his chief rocket designer, Sergei Korolyov, Khruschev lamented, "I'm only sorry that we didn't manage to send a man to the Moon in Korolyov's lifetime." Korolyov died in 1966.

Soviet disclosures, both public and private, show that they were very desirous of landing men on the Moon — and of beating the Americans there. But words are one thing, actions another. Most space engineers agree that if the U.S.S.R. had an Apollo-type program, they would have had to do the following: train cosmonauts in all aspects of a lunar landing mission, from launch to return; build a command module capable of sustaining them on a flight of lunar duration and safely returning them to Earth; construct a lunar lander; develop a Moonwalk spacesuit and equipment for use on the lunar surface; and, finally, develop a rocket booster similar to our Saturn V.

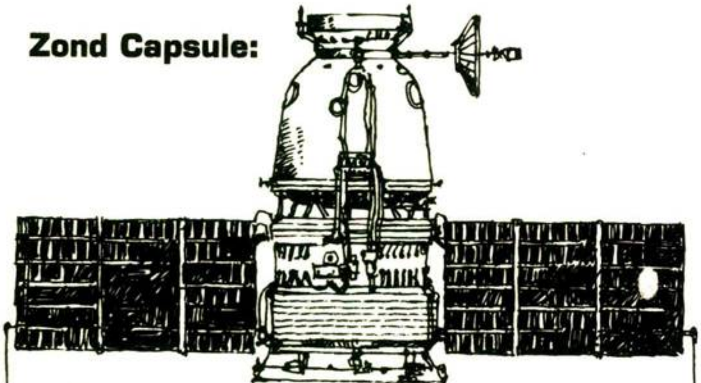
Until 1965, the Russians hadn't achieved any of these requirements, but then again, neither had the Americans. The popular press tended to view space technology in a United States context — that is, if the U.S. achieved a certain space capability at a certain time, then all other countries would follow the same path in the same sequence. This attitude, which is still in fashion, opened the door to drastic misinterpretations of Soviet efforts.

On March 18, 1965, Voskhod 2 blasted into orbit with Pavel Belyayev and Aleksei Leonov aboard. During the mission, Leonov left the craft; he drifted and somersaulted for 10 minutes in space to make the world's first space walk. Leonov's suit was entirely self-contained;

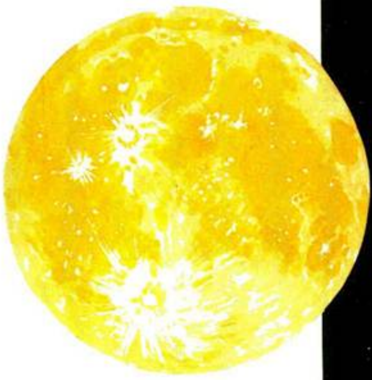


The three major parts of the Soyuz spacecraft are (top to bottom): the spherical orbital module (with a pronged docking adapter on the end), the bell-shaped descent module, and the cylindrical instrument assembly module. Two solar panels extend outward from the instrument assembly. NASA photo.

Zond Capsule:

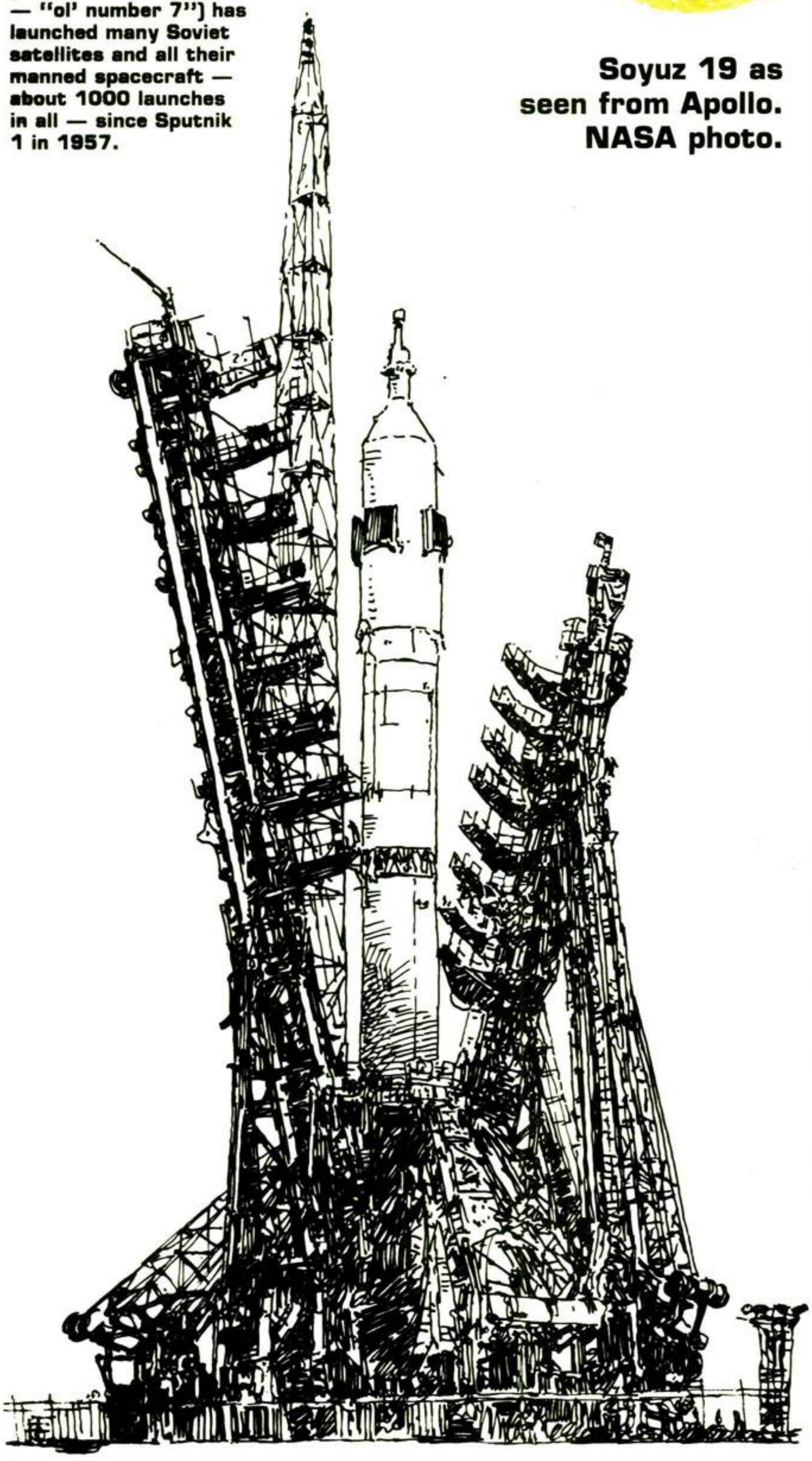


The Zond circumlunar craft is essentially a bell-shaped Soyuz descent module attached to a cylindrical service module. Although designed to carry cosmonauts to lunar orbit, it lacks any provision for descent to the lunar surface.

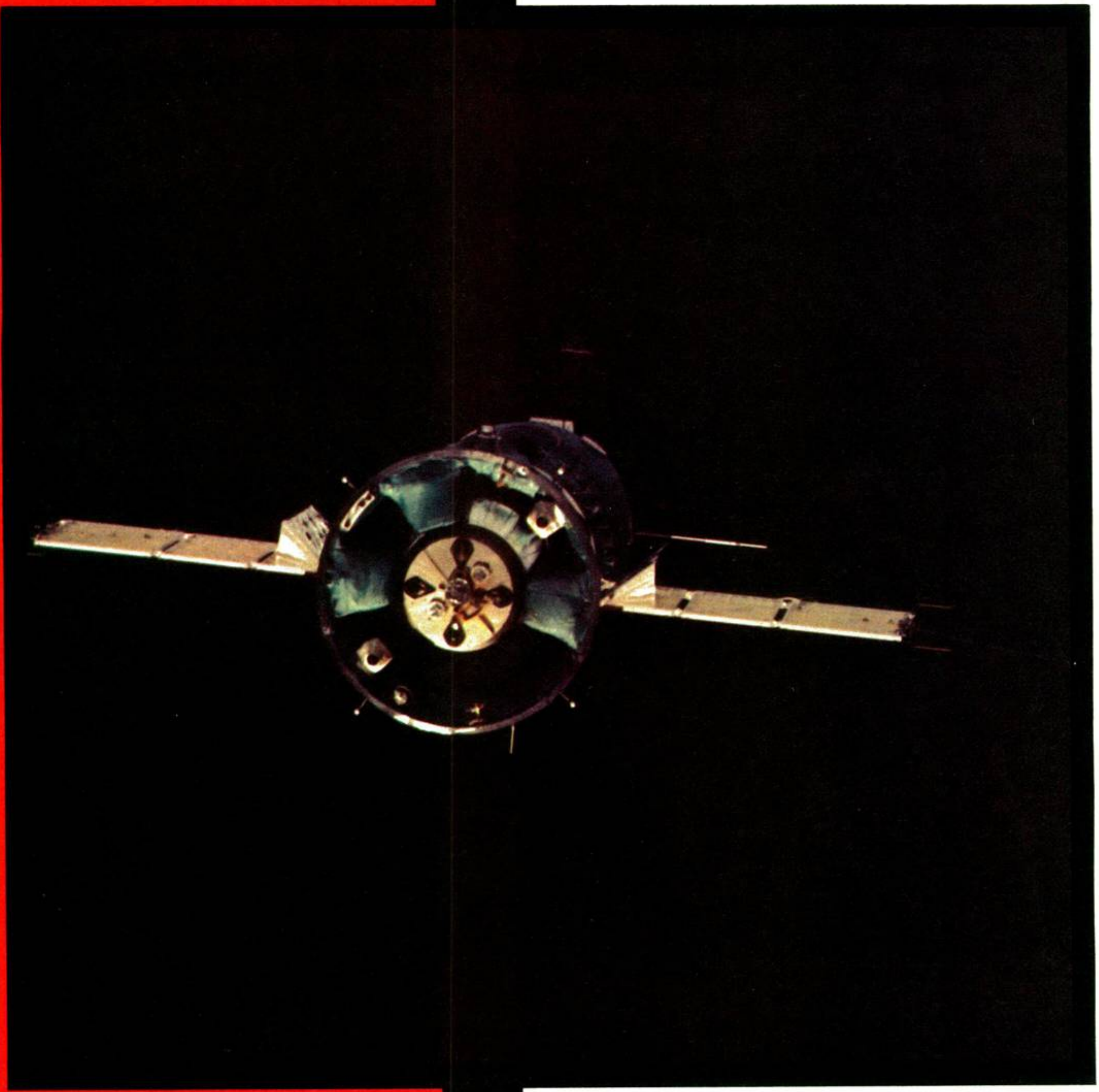


The R-7 booster:

Standby of the Soviet space program, the R-7 booster (nicknamed *semyorka* — "ol' number 7") has launched many Soviet satellites and all their manned spacecraft — about 1000 launches in all — since Sputnik 1 in 1957.



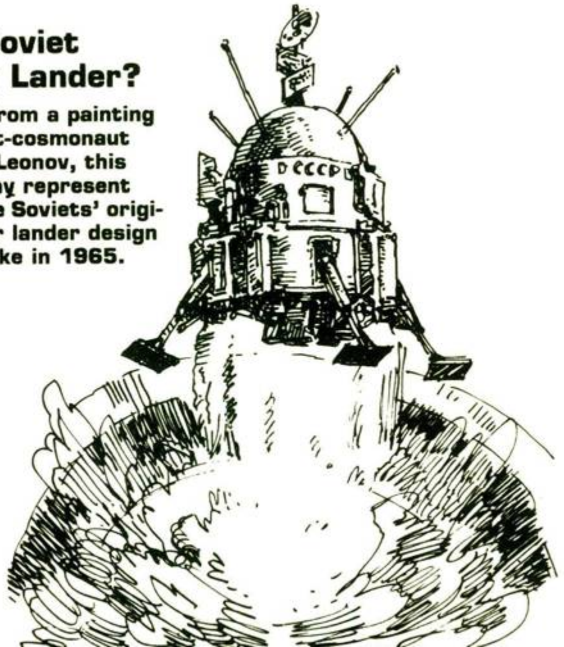
Soyuz 19 as seen from Apollo. NASA photo.



A rear view of Soyuz 19 taken during the Apollo-Soyuz Test Project mission in 1975. Analysts believe this was one of the first times the Soyuz flew with its redesigned fuel tanks. These hold less than the older models, which leads to speculation that the earlier Soyuz version had been intended for missions of longer duration — to the Moon, perhaps. NASA photo.

The Soviet Moon Lander?

Drawn from a painting by artist-cosmonaut Aleksei Leonov, this craft may represent what the Soviets' original lunar lander design looked like in 1965.



he was breathing oxygen provided solely from a backpack. He was connected to the Voskhod craft by a tether and a radio cable.

At first glance, Leonov's suit may not seem extraordinary. But if you compare the Russian suit with its Gemini counterpart, it becomes obvious that Leonov's suit was over-designed for a simple space walk. Space-walking Gemini astronauts, for example, depended on an umbilical tether to get all their oxygen. It is not stretching inference to call Leonov's space walk suit the forerunner of a lunar version. On Radio Moscow following the flight, one scientist declared that "Leonov's space walk strengthens the confidence that the first people on the Moon will be Soviet people." And in a TASS news story, journalist V. Krichagin reported that "this spacesuit may be used for landing on the lunar surface."

In contrast, a U.S. lunar suit wasn't tested until March 1969, when astronaut Rusty Schweickart wore the Apollo suit for 37 minutes in Earth orbit. Moreover, Schweickart did not float in space as his Soviet counterpart did, but instead stayed on the Lunar Module's front hatchway for almost the entire time.

Another link in the evidence for a Russian lunar landing effort concerns training. In August 1967, TASS reported that 10 cosmonauts (including Leonov) were practicing water-landing exercises in the Black Sea. No additional details were given, but they might have pointed out that all their manned spaceflights up to that time (and since) had touched down on land, while two of the Zond Moon probes had splashed down in the Indian Ocean. Why were the Soviets practicing water landings, if they were not planning Moon flights?

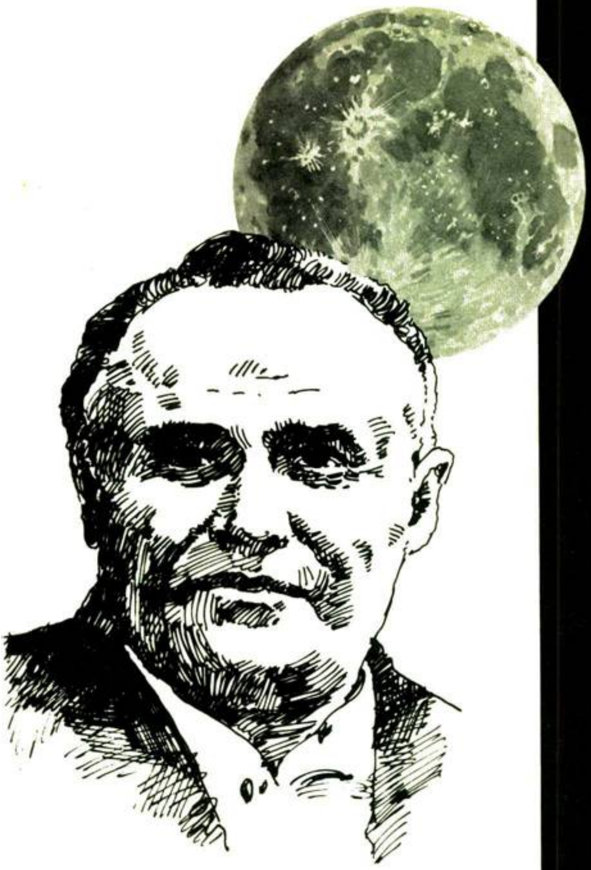
More significantly, the Soviets were training cosmonauts in helicopters and lunar simulators. Astronaut Michael Collins had learned this from his Soviet cohorts at the 1967 Paris Airshow. In the Apollo program, helicopter training was an integral part of the lunar landing effort. As Collins noted in his memoirs, "If the Russians weren't interested in a manned lunar landing, if — as they subsequently said — they were not racing us to the Moon, then why . . . were they training cosmonauts to fly helicopters?"

Soviet lunar simulators were mentioned in both Western and Soviet publications during the mid- and late-60s. In the internationally-authored *McGraw-Hill Encyclopedia of Space* (published in 1968), the section on NASA's simulators made specific mention of similar Russian activity: "Through lack of information on Soviet intentions, we shall have to restrict ourselves in what follows to American examples. There are, however, similar simulators in the Soviet Union."

The Russians declared as much in a book they published about cosmonaut training where one table, headed "specialized simulators," listed landing and takeoff from the Moon. In 1974, defector Leonid Vladimirov (who had been close to the Soviet space flight establishment) revealed that the Voronin Space Life Support Center near Moscow was involved during 1965 and 1966 in modifying the Earth-orbital Soyuz spacecraft to fly through "near-moon space." The center was known for its simulator-development work and undoubtedly, had built trainers for cosmonaut practice in operating the new spacecraft.

Also being developed in the late 60s was equipment that Russian cosmonauts would use on the Moon. In an early 1968 issue of a Soviet engineering magazine, an

Lyndon Johnson:
As John Kennedy's chief overseer for the American space program, Johnson was an enthusiastic supporter of the American space program.



Sergei Korolyov: Officially titled Chief Rocket Designer but often dubbed the "Russian von Braun" by the American press, Korolyov got the Soviet space program under way in the 1950s. His untimely death in 1966 contributed heavily to the Soviet failure to beat America to the Moon.

engineer identified as Zhitomirskiy described the workings of an automatic drill for lunar soil sampling. The drill, designed to bore to a depth of about 4½ feet, could recover up to six samples. Other hardware such as handheld cameras that would operate in a lunar environment and a two-wheeled cart similar to that used on Apollo 14 were also in advanced stages of testing.

During 1968 to 1970, several lunar probes designated as part of the Zond program, were launched by Proton boosters on circumlunar trajectories. Official depictions of these Moon orbiters show a remarkable resemblance to the manned Earth-orbital Soyuz craft, except that the Zonds had no forward orbital module. The Zond mission profile raised NASA suspicions that the probes were not just run-of-the-mill vehicles. During the flights, for instance, several taped voice transmissions were made to Earth at varying distances, and, on reentry, the descent modules executed double-skip, G-reducing maneuvers almost identical to those performed in the Apollo program. (The maneuvers kept G-forces within five gravities — an amount that can be safely endured by crew members.) These similarities to a manned Moon flight profile were confirmed when a dark, grainy photograph was identified as a Zond spacecraft undergoing a launch-escape test. This was final proof that the Zond craft were to have been manned. Unmanned spacecraft do not need escape towers.

The Soviets themselves revealed the true intent of the Zond missions. *The Soviet Encyclopedia of Spaceflight*, published in mid-1969, stated that "Zonds 4, 5, and 6 were launched for flight testing and further development of an automatic version of a manned lunar spaceship." In an early April 1969 broadcast on Radio Moscow, Academician Mstislav Keldysh emphatically stated: "The Zond flights tested the path of piloted spaceships to the Moon, and ships of that class can themselves carry men."

Was a Zond spacecraft ever manned for an operational mission? According to space analysts, the answer is probably yes. Supporting evidence comes from both NASA and the Russians.

During most of 1968, rumors in the international astronautics community told of a manned Soviet space spectacular before the end of the year, and it would most likely involve the Moon. These stories were given legitimacy by cosmonaut Gherman Titov, pilot of the second Vostok. In late October 1968, Titov was in Acapulco to observe the Olympic yachting trials. While being interviewed by a French newsman, Titov let slip that he had been chosen to pilot the first Russian spacecraft to the Moon, but that he didn't know when the actual flight was scheduled. "The U.S.S.R. is ahead of the U.S.A. in a space race," he confided.

A week later on Radio Moscow, Titov stated that the journalist misquoted him and that no manned Moon shot was imminent. However, five days after this denial, Zond 6 was launched. After its bump-down on Soviet territory, TASS reported — in an about-face of the official line — that the next Russian Moon mission would probably be manned.

To add further confusion, and almost simultaneous with successful completion of the Zond 6 flight, NASA changed its upcoming Apollo 8 from an Earth-orbital test of the command module/Saturn V booster to a circumlunar mission. Robert Gilruth, former director of Houston Mission Control, revealed in 1977 that the Apollo 8 flight schedule was changed in part due to pressure from an expected Soviet event — a manned circumlunar shot sometime in December.

Two more facts added to NASA's worries, and made it clear the U.S. was in danger of losing its chance to be first to put men into lunar orbit. First, because of orbital mechanics, lunar launch windows (the times most advantageous for a Moon launch) always open for the Soviet Union 12 days before the U.S. Second, rumors were circulating in Moscow of a call sign, "Diamond," for an imminent lunar spaceflight — the Soviets use call signs only on manned missions. Adding urgency was the fact that many NASA officials believed the Apollo program would fall into jeopardy if the Russians sent a man to the Moon first.

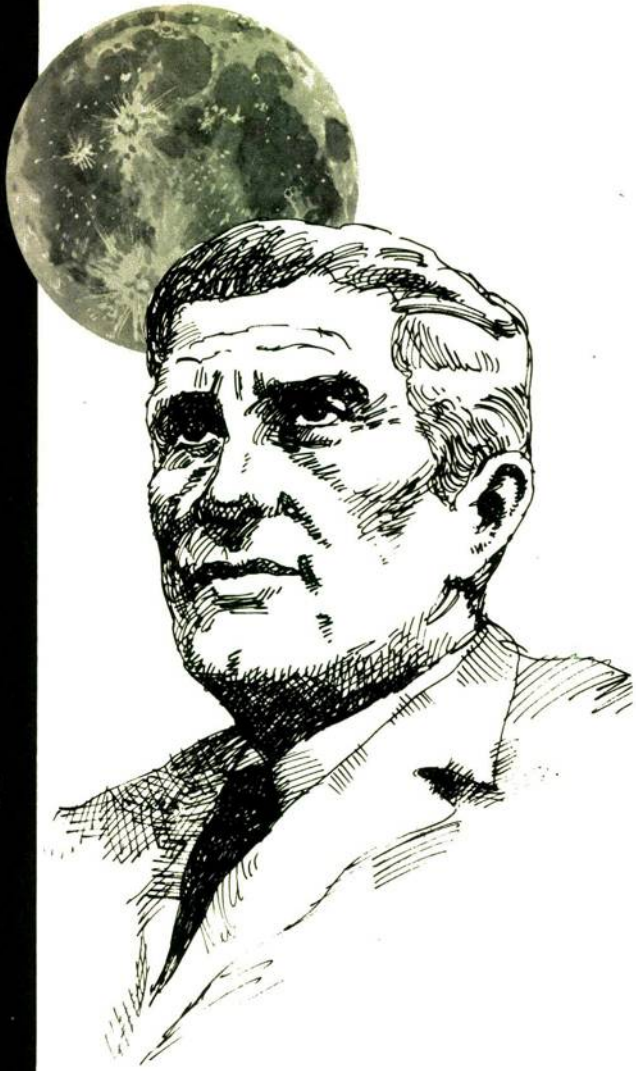
About December 2, 1968, a Zond spacecraft and Proton booster were erected on a pad at Tyuratam launch site in Soviet Kazakhstan, in preparation for a launch within the week. A cosmonaut was flown in from the Gagarin Training Center near Moscow and placed in the Zond on December 9th. The countdown went off without a hitch, but the launch was cancelled. From information gleaned by Western experts, there seems to have been an electrical problem in the spacecraft. The problem was corrected, but launch officials scrubbed the flight for an as-yet-unknown reason.

The rest of the circumlunar race is history — Apollo 8, the first operational mating of the Apollo spacecraft with the Saturn V booster, became the first manned spacecraft to orbit the Moon. This engineering feat would not have been possible without NASA's policy of "all-up" testing, where all components of a mission are tested at one time instead of piecemeal in separate flights. In contrast, the Soviets had executed three lunar flybys as unmanned dry runs, using their man-rated spacecraft, before the December 9th launch failure.

But flybys, however historic, are not landings. Did the Russians have a craft to take them from lunar orbit down to the Moon's surface? And if they did have a lander craft, did they have a booster rocket powerful enough — Saturn V class — to take it to the Moon? Neither lander nor booster has ever been identified in official Soviet photographs, nor has either been admitted to exist. However, Western analysts have evidence that confirms both vehicles were tested. This confirmation comes from examining several obscure Soviet Moon-related missions, and from the Central Intelligence Agency and NASA.

Most space experts and observers believe that several lunar-related flights, before and after Apollo 11, incorporated hardware developed for the Soviet lunar lander. The later space shots in the Luna series — Luna 16, which returned 3.5 ounces of lunar soil in September 1970, and Luna 17, which soft-landed the first robot lunar rover in November 1970 — probably used lander components for their descent stages. In comparison, Luna 15 (which crashed the day after Neil Armstrong set foot on the Moon) is believed by some analysts to be a stripped-down version of the actual Soviet lunar lander. (See the box on page 21.) However, other analysts think that Luna 15 was a failed attempt to retrieve a lunar soil sample. They point out that Luna 15's estimated weight was nearly identical to that of Lunas 16, 18, 20, and 24 — all of which either attempted or successfully carried out a soil-return mission.

The evidence doesn't end here, either. During the nine-month hiatus in the U.S. program following the Apollo 13 accident, four Earth-orbiting Cosmos flights (late November 1970 to August 1971) performed orbital maneuvers very similar to tests conducted by the Apollo



Wernher von Braun: Chief architect of the American space program, von Braun was largely responsible for creation of the gigantic Saturn V booster — essential for carrying an American crew and lander to the Moon.

9 astronauts with the American Lunar Module during March 1969. On all four of these mysterious flights, taped voice transmission tests were conducted.

During its mission in early December 1970, Cosmos 382 separated into three parts. It duplicated a lunar-orbit injection, a descent, and — when one module soared to a height of 2,600 kilometers above the Earth — a test of a lunar landing abort. Cosmos 382 is believed by most space experts to have been the all-up test of the Soviet lunar lander in Earth-orbit. Another Earth-orbital flight, Cosmos 434, was launched in mid-August 1971 and performed similar maneuvers. On its recent decay into the atmosphere (August 1981), the Russians described the spacecraft's mission as "a test of an experimental lunar cabin."

If the Soviets were conducting tests of a lunar lander a year or two after the Apollo 11 landing, this still doesn't prove they had a lunar lander in the summer of 1969. On the other hand, many analysts feel that the Soviets *did* have a lander then, but not one able to put down on the surface of the Moon. The analysts believe the vehicle was still being developed, but that cosmonauts could test it in lunar orbit without going so far as to actually descend to the surface.

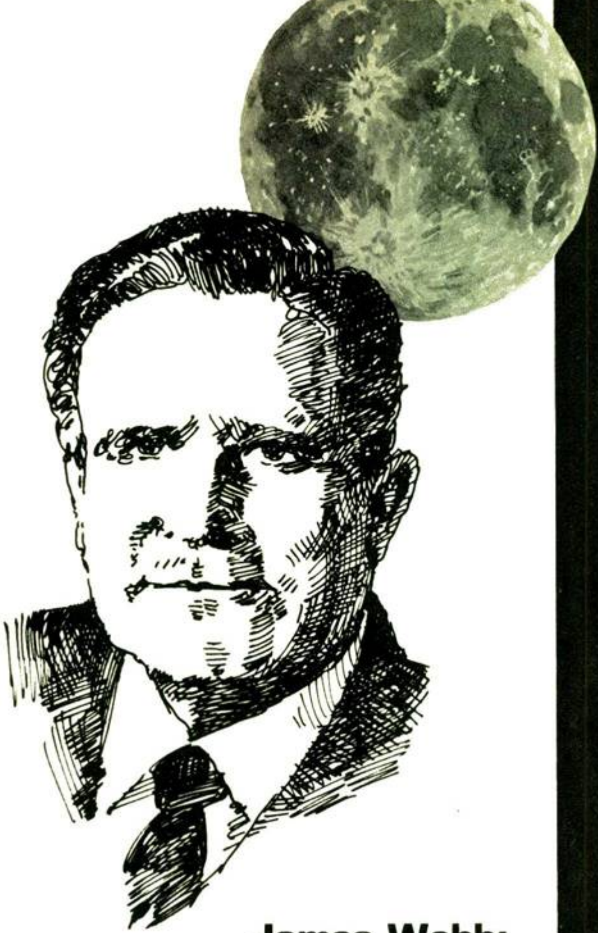
In 1967, during agency budget hearings in Congress, NASA Administrator James Webb brought up information that told of a monster rocket the Soviets were building and testing in "bolt-down" firings at Tyuratam. When asked by congressmen for evidence, Webb informed them that secret reconnaissance pictures showed a booster about 400 feet tall with giant assembly towers next to the launcher. This rocket, designated the TT-5 or G-1, had twice the power of America's Saturn V which generated 7.5 million pounds at lift-off. Webb claimed this was proof that the Kremlin was working to put men on the Moon.

Lacking any evidence other than Webb's word (they weren't allowed to see the reconnaissance pictures), many congressmen suspected that the super-rocket and Soviet Moon landing preparations were simply a ploy by NASA to get more funds. They dubbed the booster "Webb's Giant," and when no confirming facts were made public, even years after Webb's departure from NASA, most considered the vehicle a myth.

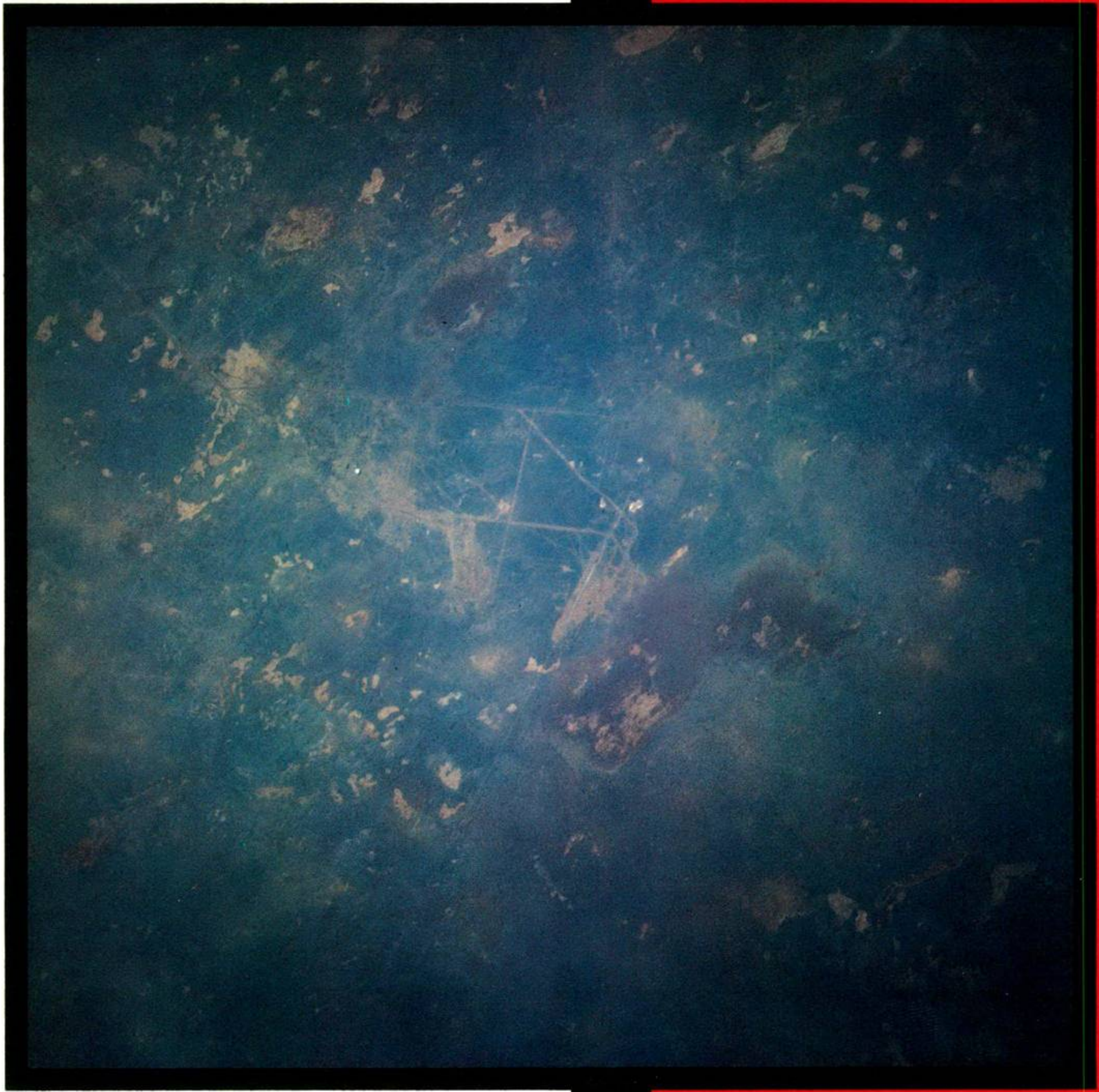
But the G-1 was a physical fact. At a March 1976 American Institute of Aeronautics and Astronautics conference in Washington, D.C., several unidentified senior CIA officials publicly disclosed that the Russians had the rocket program Webb claimed. They also said the program's sole purpose was to put cosmonauts on the Moon concurrent with American lunar landings. One launch attempt, the CIA spokesmen revealed, took place in the summer of 1969.

Following Apollo 8's bold success in December 1968 and Apollo 9's triumphant testing of the lunar module in March 1969, the Russians may have begun working on a plan to upstage the Americans. Their own manned circumlunar shot in early December had been cancelled and a probable lunar soil-return attempt in April 1969 had exploded on the launch pad. The first hint of the Kremlin's plans was given at an international symposium on space science held in Venice following Apollo 10's May 26th return to Earth. CIA informant Peter N. James, who wrote about his experiences in *Soviet Conquest from Space*, attended this symposium.

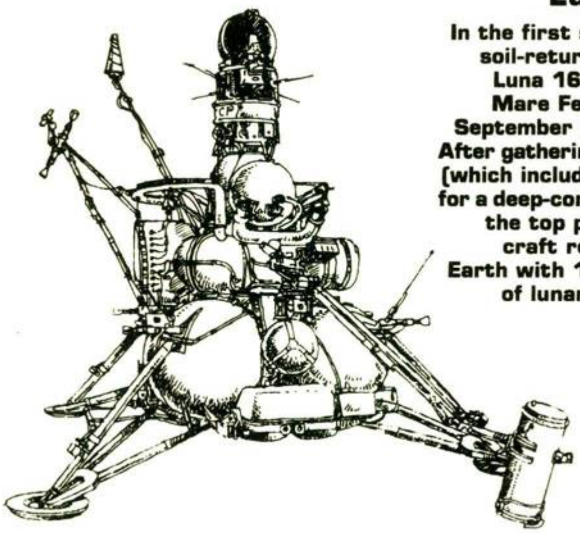
James, a Soviet space-technology specialist, had good friends among the Russian group that was attending the meeting. The group, mostly scientists, also included a few



James Webb: While NASA Administrator under John Kennedy and Lyndon Johnson, Webb issued repeated warnings of Soviet work on a gigantic booster — but nobody believed him.

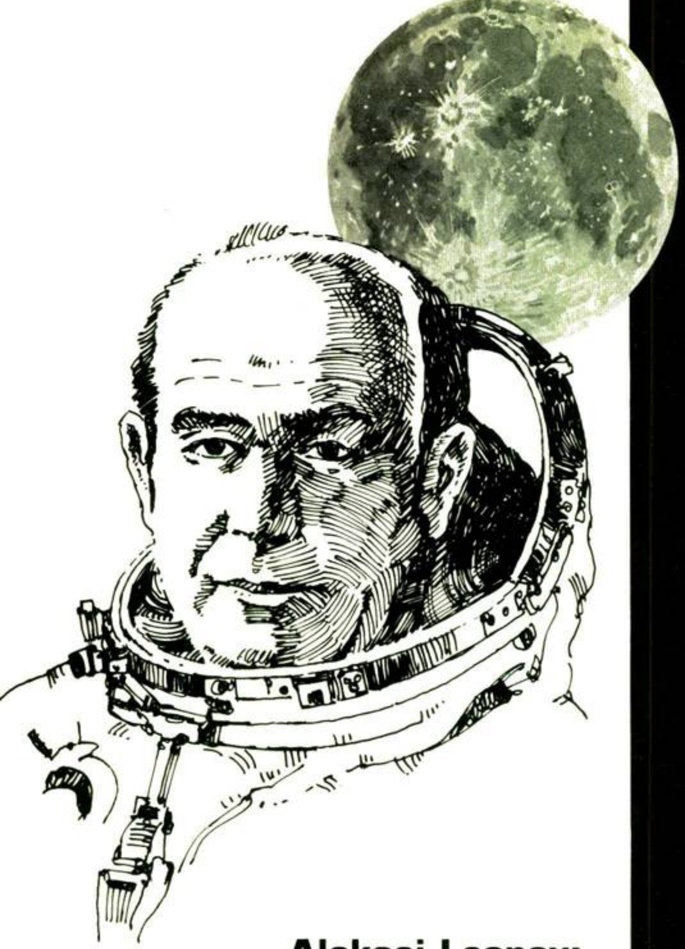


The town of Tyuratam on the Syr Darya River in Soviet Kazakhstan was photographed on orbit 59 of the STS-10 Shuttle flight in November 1983. Deceptively mislabeled "the Baikonur Cosmodrome" by the Soviets, the Tyuratam launch site lies 15 miles north of the town and some 200 miles southwest of the actual village of Baikonur. All manned Soyuz launches originate here.



Luna 16:

In the first successful soil-return mission, Luna 16 landed on Mare Fecunditatis September 20, 1970. After gathering samples (which included drilling for a deep-core sample), the top part of the craft returned to Earth with 100 grams of lunar material.



Aleksei Leonov:
The suit Leonov wore for the first space walk in history may have been a preliminary version of the Soviet Moon suit. He was also commander of the Soyuz spacecraft that linked up with an Apollo Command Module during the Apollo-Soyuz Test Project in 1975.

cosmonauts and KGB agents. At one evening reception, James recalls a heated debate with KGB Colonel Nikolai Beloussov:

"He had just paused in one of his friendly denunciations of U.S. policy, when I told him 'All things considered, the U.S.A. is going to beat the U.S.S.R. to putting men on the Moon, and you Soviets can't do a thing about it.' Beloussov, who had been looking at the ceiling with a drink in his hand, fired back, 'You may be surprised!' He then paused, considered what he had just said, and then walked away. Right then I knew the Russians had some type of Moon launch before Apollo 11."

Beloussov's retort was reinforced by three events that took place in June. Early in the month, cosmonaut Aleksei Leonov created a stir when he revealed in a Japanese interview that, "We are confident that pieces of rocks picked from the surface of the Moon by Soviet cosmonauts will be put on display in the Soviet pavilion during the World Exposition in Osaka next year." In mid-June, Soviet tracking and support ships began steaming for stations in the Pacific, Atlantic, and Indian Oceans. And on June 18th, a U.S. Navy contingent of two destroyers and several support ships began operating in the Black Sea.

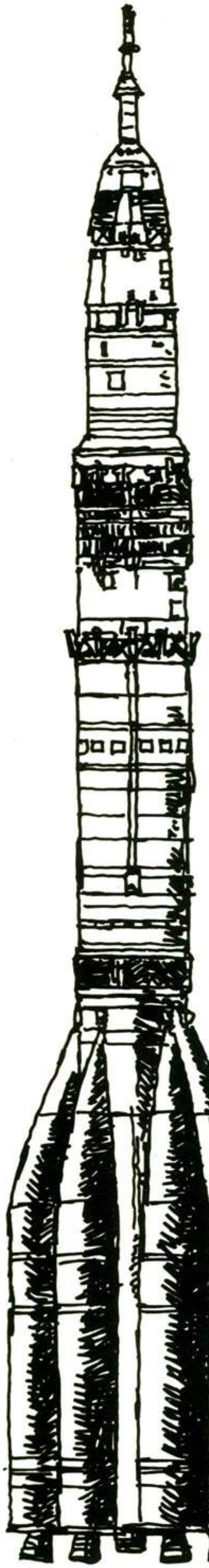
By the end of June or early July, rumors leaking out of Moscow hinted that the Soviets were about to perform a lunar spectacular within a few days; several accounts tied these reports to a giant rocket in the Saturn V class. According to Peter James, these rumors were taken seriously and prompted the U.S. Navy to send ships into the Black Sea to monitor the attempt.

At Tyuratam, the much-rumored G-1 rocket and its smaller Proton counterpart were erected at their respective pad sites sometime in mid or late June. The payload for the Proton launcher was a manned Zond spacecraft; for the giant G-1 booster, it was an operational lander with an added fuel stage.

Western analysts believe that the mission was to have gone as follows: The G-1 would be launched first. After one orbit, the Zond and its cosmonaut crew would be fired into orbit and dock with the lunar lander/fuel stage complex. With all systems "go," the entire assemblage would leave for the Moon. Several days later, when the spacecraft assembly was well on its way, another Proton rocket would be launched toward the Moon with a lunar soil-sampling spacecraft aboard. The cosmonauts would orbit the Moon and test the lunar lander — a mission similar to the American Apollo 10 flight. Meanwhile, the unmanned spacecraft would descend to the surface and gather a sample of lunar soil, then both spacecraft would return to Earth triumphantly. This plan would leave the question as to whether or not the cosmonauts actually landed on the Moon comfortably vague, and the Soviets could truthfully claim they had brought back Moon rocks. Meanwhile, the Apollo 11 mission — if it hadn't already been cancelled — would still be traveling outward from Earth on the first leg of its mission.

As June 1969 waned into July, three men from the cosmonaut corps were flown from the Gagarin Training Center to Tyuratam. On the morning of July 4th, the men entered their Zond spacecraft.

A planned series of holds delayed the countdown until early afternoon, when the first launch signal was given. The G-1 booster roared to life and rose from the pad, but the rocket never cleared the launch tower. Some analysts believe that on-board sensors detected a fuel-flow problem and shut down many of the engines. Other



Zond Booster:

Carried aloft on a "Proton" class booster, the Zond craft was a lunar spaceship. No Zond flights to lunar orbit were manned, but the launch escape tower on the nose of the rocket shows that manned missions were being planned.

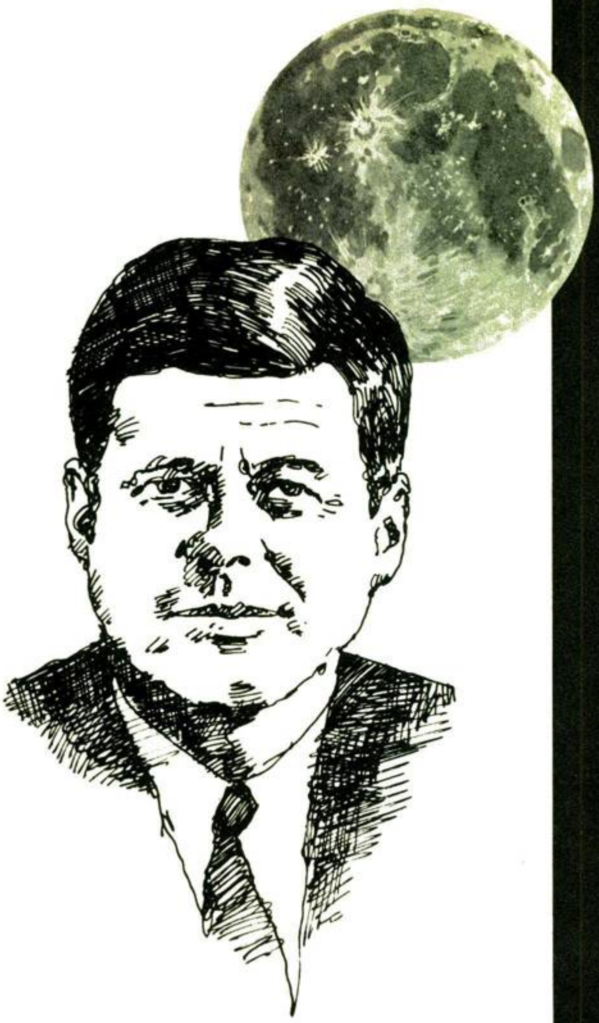
Was Luna 15 the Soviet Moon Lander?

Luna 15, launched on July 13, 1969 from Tyuratam, impacted the lunar surface one day after Apollo 11 set down on the Sea of Tranquillity. To this day, the intent of its voyage remains a mystery. Some Western space experts think Luna 15 was a failed lunar soil-return attempt; other analysts believe the spacecraft was something more — perhaps the precursor of a manned lunar lander — and point to several items connected with the flight as evidence.

Luna 15's reported weight was 6,500 pounds — 1000 of which were payload. When this weight is compared with the descent weight of the manned American Lunar Module (11,600 pounds), the Soviet spacecraft begins to take on the appearance of a stripped-down lunar lander. Another factor to consider is the vehicle's behavior while it was orbiting the Moon. From July 17 to July 21, Luna 15 performed four orbit changes — believed to be more than any other Luna-series craft. The amount of propellant expended for these orbital maneuvers indicates that Luna 15's design may have been different from later Lunas used for soil-return missions from the Moon.

Another fact raised by those favoring the manned lander theory is that the Russians have never revealed what Luna 15's mission was — even 15 years after the event. Perhaps this is linked to previous Soviet statements that mentioned plans to use animals as the first lunar inhabitants. For instance, in early February 1966, TASS interviewed cosmonaut Gherman Titov, who discussed tentative lunar landing plans: "I expect that live organisms would visit the Moon before man sets foot there — probably dogs." Other cosmonauts and space officials reiterated Titov's comments. In August 1968, Academician Boris Petrov told an Austrian audience that "We intend to conduct the entire operation of landing and returning automatically several times, and a dog may go to the Moon and back before we send cosmonauts."

A case could be made that Luna 15 had one or more dogs aboard, and that the Soviets may have been counting on Apollo 11 to abort its landing. This would have allowed the Russians to claim they had put the first living creatures on the Moon. If this had been the Soviet plan, their hopes were dashed when Apollo 11 landed successfully.



John Kennedy:
Stung by the Bay of Pigs fiasco, Kennedy committed the U.S. to a Moon landing in 10 years' time to demonstrate the superiority of American technology over the Soviets' — and to restore damaged national prestige.

analysts think that the second stage collapsed. In any case, the rocket fell back on the pad and blew up. Everything within a mile was either destroyed or heavily damaged in the fiery explosion. The gantry, observation towers, support equipment, and pieces of the launch pad itself flew in all directions, while some of the attending Soviet engineers perished. Another G-1 pad complex half a mile away was heavily cratered.

In orbit, USAF Ferret-class satellites detected a strong disturbance of the terrestrial magnetic field, while NASA weather satellite Nimbus III registered the explosion on its slow-scan infrared sensors.

The simultaneous countdown of the Proton booster/Zond spacecraft was halted and the cosmonauts left the capsule. With this, the Soviets lost their last chance to upstage Apollo 11. Over the next several days, the Russian tracking and communications ships quit their stations and headed back to port.

When the unmanned Zond 7 completed its flight in August 1969, the descent module had probably been occupied by the three men who had awaited the launch signal just a month before. As Soviet space officials recovered the Moon-probe from the wheatfield, the lame success of this flight was the bitter end to a major investment in spaceflight by the U.S.S.R.

Despite Russia's failed attempt to upstage the U.S., equipment that was in development (such as the lunar lander) was allowed to continue. Soviet hopes to land men on the Moon may have been resurrected when Apollo 13 had its near-fatal mishap in April 1970. That hope was short-lived, for Apollo 14 successfully landed near Fra Mauro crater in February 1971.

A nagging question remains: Why haven't the Russians landed on the lunar surface anyway, since most of their equipment was apparently ready by the summer of 1971? The answer, unfortunately, comes down to ideology: the Soviets consider spaceflight a political gambit. They have lagged behind the Americans in almost every area of expertise, except that which symbolizes the future — space technology. During the early 1960s, following every Sputnik and Vostok flight, Premier Nikita Khrushchev crowed about Russian superiority and challenged the U.S.A. to overtake them. The Americans finally did. By the early 1970s, the Soviets recognized a lost political battle. They clearly saw little fame or glory in being the *second* nation to put men on the Moon — despite promises to the contrary, billions of rubles, and who-knows-how-many lives already spent.

Current Soviet space activity focuses closely on space stations. The Salyut series was first launched in 1971 and the present station, Salyut 7, has been inhabited almost continuously since its launch roughly three years ago. The Soviets hold the record for the longest space flights — well over 200 days — and have accumulated a wealth of data on the medical problems of extended weightlessness. This information would be invaluable in planning a mission to Mars.

The Soviets may still land men on the Moon, but NASA has no definite plans for returning there before the year 2000. So while the American space program captures world headlines with transient firsts from the Shuttle program, the Soviets continue to plod toward their renewed goal — permanent preeminence in space.

Peter Pesavento is a free-lance writer and interested observer of the American and Soviet space program.

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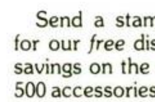

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"You Are Going to an Expedition, Not to London" The Indonesian Total Eclipse of the Sun

For P.A.

Saturday, June 11, 1983. This morning we find ourselves crouching at the side of a road running between hot, wet Indonesian rice fields. This is supposed to be the dry, comfortable season here, near the shortest day of the year. But in this equatorial region, the longest day gains only 49 minutes on the shortest day, and one can easily overdo anytime in this tropical steambath, where fingernails and hair grow faster, dry skin becomes baby-soft, and fat melts off one's body like butter. Except for the usual rooster-crowing in the distance and an occasional passing car, our unmarked rural area close to the shade of a tree is quiet. There are no workers in the fields because the government has convinced its people that blindness will surely result from viewing this eclipse. Banks, schools, streets — indeed, whole cities — were closed up as we sped the 60 miles from Surabaya to just south of Tuban, a little village on Java's northern coast. Our new Indonesian friend Paulus, in whose car we have come, also found this drive eerie. He later described it in a letter to us: "Riding a car on an empty road passing villages and villagers' houses firmly closed — afraid to be out in their yards — we are passing by like a most cruel bandit in a cowboy film."

Now, Paulus and his driver aren't saying much, but they are courageous enough to look through our filtered telescope at the slowly decreasing crescent resulting from the Moon slipping over the Sun. They're waiting to see just what this eclipse fuss is all about. We who have flown in from the other side of the world are practically walking on air, excited and expectant.

We had met our host at a small orchid-strewn native hotel where we were staying in Surabaya.

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Unexpectedly he volunteered his car — a means for us to reach this spot precisely on the central line of totality and at the same time retain the mobility essential for successful eclipse chasing. At the last minute, he had even decided to come along with us. Twice on the way to our eclipse spot we were stopped by the rather friendly police; this road was apparently closed for the day. "Why are you going here?" they asked. Paulus answered, "They want to see the eclipse!" We were the tourists, honored guests, and on this momentous day for Indonesia, the whole country was taking care of us.

We first contracted our bad case of eclipsitis in Oregon on a cloudy day in February, 1979. With six months of weather research, complete mobility on eclipse day, and a bit of luck, we beat the better than 80 percent odds of a completely overcast sky and saw almost all of the two and a third minutes of totality there. It was a stunning experience. The transitions to Baily's beads, to the diamond ring, and finally from daylight to darkness and back were sudden, startling, and abrupt — literally taking one's breath away. And the darkness was surprisingly deep, almost like the dead of night. In seconds, heavy dew began to accumulate as the air cooled further. Clouds obscured the Sun's wispy corona, but sparkling ruby-red prominences were visible even without optical aid.

We didn't get to the African eclipse in 1980, but there gradually dawned the possibility of Java in 1983. We began to save our dollars and look for cheap travel to and within Indonesia. In the end, we found that the two of us could spend an entire month in Indonesia, traveling to and from the West Coast, for less than it would cost one person to go on the cheapest advertised eclipse tour for little more than a week. One person could fly to

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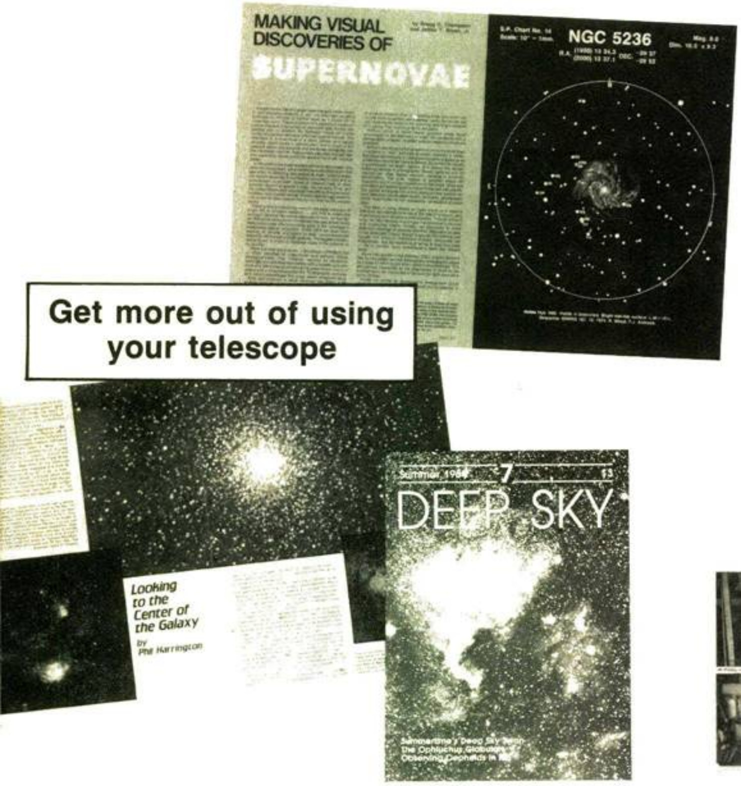
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Indonesia, travel around Java and Bali for a month, and return to the U.S. for somewhat under $1500. And so it was that we were able to see an eclipse that was as perfect for gentle Java and its smiling people as was the stunner in cold Oregon.

10:00 a.m. The silent show begins. A huge set of sunspots spoils the Sun's even brightness, matching the darkness of the encroaching Moon. A 22° ice crystal halo appears around the Sun, surprising in the jungle heat and humidity (it reappeared after totality). Now there are only a few fast moving clouds — in sharp contrast to yesterday, when thick clouds covered most of Java all day. The weather inspired one local newspaper headline "Astronomers Resigned and Annoyed." Still, we maintain mobility, ready to go at a moment's notice if necessary in order to catch the sweeping shadow of the Moon.

A lone woman walks slowly down the road, resisting our tempting waves to come over and look at the Sun — called "*matahari*" in Indonesian, meaning literally "the eye of the day." But this woman is as brave in her way as Paulus and his driver were in looking through our telescope, so persuasive was the government and media warning against watching the eclipse. Our two companions are even now complaining of "aching eyes." Actually the newspapers played it both ways (as they tend to do), satirizing the concern with cartoons and then later claiming more than 400 were blinded. We asked Paulus how the Indonesians explained the fact that astronomers could look at the eclipsed Sun with apparent immunity and he replied, "Why, they just think scientists are different!"

As the minutes to totality dwindle away, and the chickens and dogs and birds begin to chant to each other, we ponder the problem of how to tell people not to look at partial phases but to enjoy in safety the naked-eye thrills of totality. Obviously, the Indonesian government had difficulty with that one — but then so did Canada and the U.S. in 1979. The officials likewise made hundreds of hotel owners all over central Java unhappy with the vastly exaggerated accounts of the half-million astronomer-tourists to expect. "Hotel Owners Curse Enormous Campaign" is how one newspaper headlined it on eclipse day. There were two official government-designated eclipse centers on Java for media and astronomers: the temple of Borobudur in the south central part of the island and Tenjung Kodok near Tuban on the northern coast. At the latter, seven other specific sites for astronomers were described in detail in an official handout entitled *You are Going to an Expedition, Not to London*. Some of the spots "limited" to 3,000 people saw only a hundred or so show up, while others remained unvisited. But in spite of the heat, getting there could hardly be called an expedition. Maybe it was the unfailing good manners of the Indonesians — or perhaps they understood too well how soft Japanese and American tourists tend to be.

We never saw such an elaborate exhibit with such colorful literature as in the eclipse information center in Surabaya. The problem was, few people knew about this center since it was located in that city's oldest and most distinguished hotel, far from the high-rise "international class" hotels favored by the astronomers. One wonders what happened to all the leftover multi-color pamphlets no one ever saw.

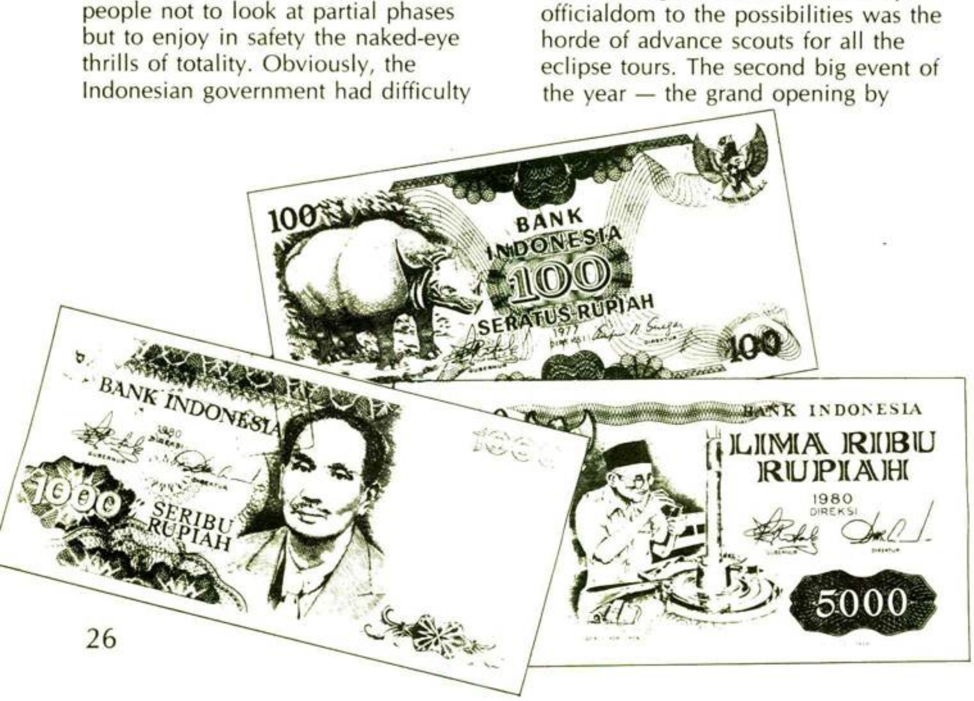
This was to be a big year for Indonesians, though it took a while for them to realize it. Hardly anyone outside of Bosscha Observatory near Bandung, Java, even knew about an eclipse until less than a year before it happened. And how many astronomers accepted the observatory's invitation to visit? We figure that what woke up officialdom to the possibilities was the horde of advance scouts for all the eclipse tours. The second big event of the year — the grand opening by President Soeharto of the newly restored Borobudur, the largest Buddhist temple in the world — came off as scheduled in February. Finally, August 26 celebrated the 100th anniversary of Krakatau, an island just west of Java on which occurred the largest volcanic explosion in human history, dubbed by the Indonesians (now up on fashionable astronomical terminology) as "the Biggest Bang."

This is all quite characteristic of the country, the fifth most populous in the world. It wants to be heavily industrialized and to attract the big tourist dollars, to carve for itself a place in the modern world commensurate with its size. And it works hard and effectively at achieving these goals. For example, Indonesia is the fourth nation in the world to own and operate a national communications satellite system (a necessity since its 27 provinces span a significantly greater distance than the continental U.S.).

But the people are so awesomely gracious, refined, cultivated, exquisite, sophisticated, in short, civilized — "alus" is their word for it — that good manners come first. They know the real delights of eating; after all, they introduced spices to the entire world. Even their language is appropriate for their character — easy to get to know. It has no plurals, no tenses, no declensions, no articles, no genders, no conjugations, not even the verb "to be." Visiting astronomers quickly became infatuated with the Indonesian term for "total eclipse of the Sun" (*gerhana matahari total*).

In the end, the Indonesian love of the controlled emotion of art, the interestingly presented meal, the quiet afternoon, and the active leisure of the evening is ultimately more important to them than the buck. Sometimes the two coincide, and the ad campaign of one of the larger Indonesian beer companies, Bir Bintang, is a good case in point. The very decision to capitalize on the eclipse was astronomically clever — "Bir Bintang" means "Star Beer," and their trademark already featured a red star. So it was easy to present a colorful red and gold picture of Rau — the Indonesian eclipse god — not only on billboards, T-shirts, and ashtrays, but on the beer cans themselves, in both Indonesian and English, complete with the date. "And now, brought to you by Bir Bintang . . . Gerhana Matahari Total, The Total Eclipse of the Sun!"

In total silence, Baily's beads slowly begin to form, then gradually merge into a brief diamond ring. No shadow bands, no fast-moving shadow coming, no sudden startling *click* as in Oregon in 1979, but gently, almost carefully, the delicate lacy corona appears surrounding the round darkness of the hidden Sun. We can see the corona —



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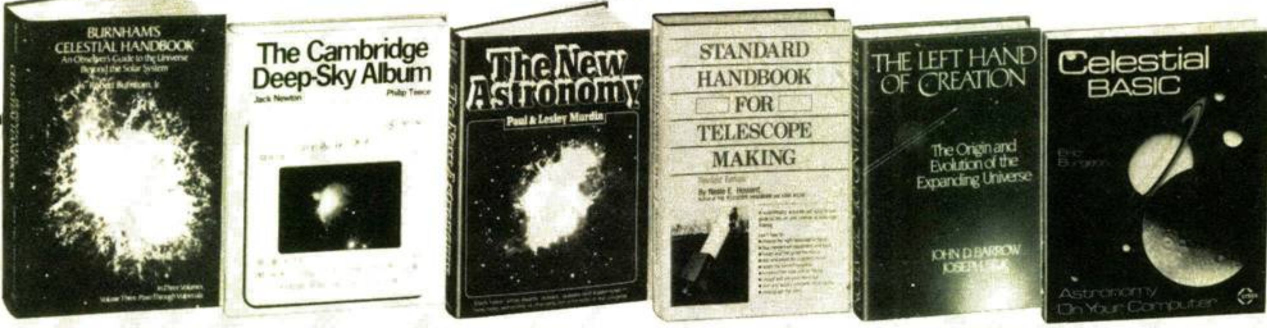
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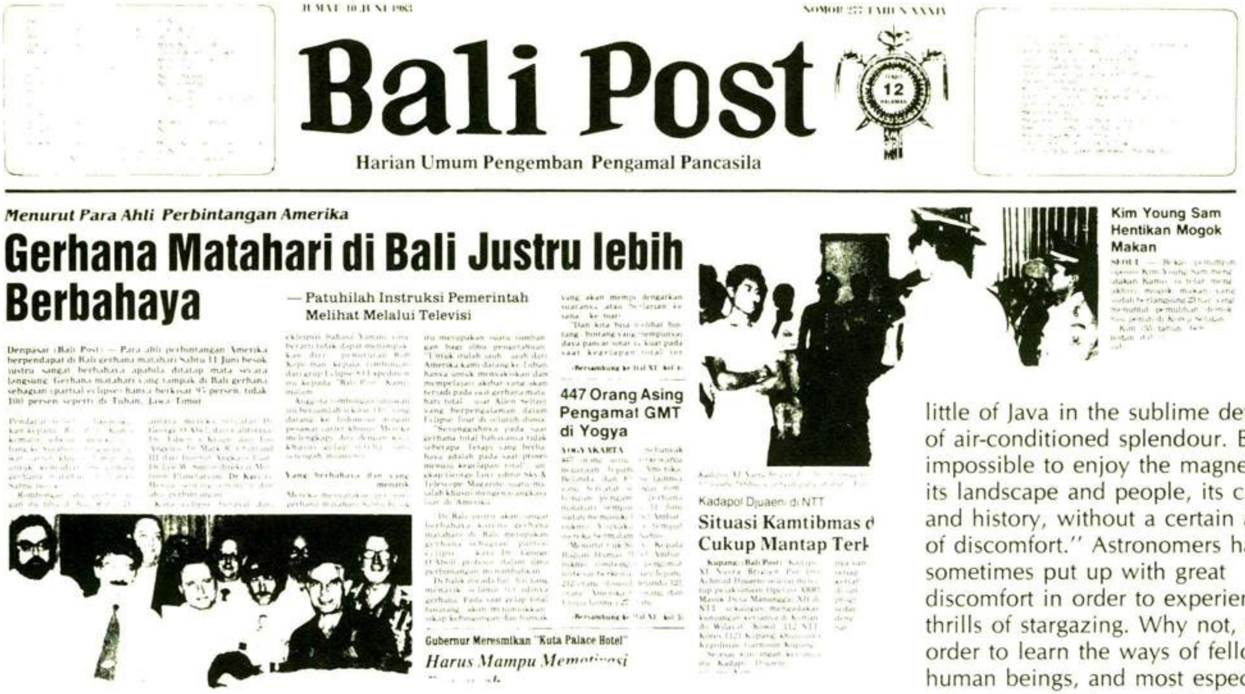

JUMAT 10 JUNI 1983

Bali Post

Harian Umum Pengemban Pengamal Pancasila

Menurut Para Ahli Perbintangan Amerika

Gerhana Matahari di Bali Justru lebih Berbahaya

— Patuhilah Instruksi Pemerintah Melihat Melalui Televisi

Denpasar (Bali Post) — Para ahli perbintangan Amerika berpendapat di Bali gerhana matahari Sabtu 11 Juni besok justru sangat berbahaya apabila ditatap mata secara langsung. Gerhana matahari yang tampak di Bali gerhana sebagian (partial eclipse) hanya berkisar 95 persen, tidak 100 persen seperti di Tuban, Jawa Timur.

447 Orang Asing Pengamat GMT di Yogya

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Situasi Kamtibmas d Cukup Mantap Terk

Kim Young Sam Hentikan Mogok Makan

Gubernur Meresmikan "Kuta Palace Hotel"

Harus Mampu Memotivasi

our first! And the sky isn't starlit black as in Oregon, but rather soft grey-orange all around the horizon, more color in the east at first, then more in the west as totality proceeds. A simultaneous reddish sunset and sunrise glow slowly caresses us while overhead the sky is still blue, though of a darker hue than the usual daytime color.

How far away out in space the Sun is! It somehow looks oddly small, like a black beauty mark painted on the sky in this spectacular performance on the largest screen in the universe.

We see no naked-eye prominences this time, but in binoculars and telescopes there is one beautiful set visible at the beginning of totality. And in the binoculars there's Mars just at the edge of the corona. But it's the brilliant corona itself that mesmerizes us. With its subtle curves and lines and brushes, the magical corona appears to move slowly as though swaying in the solar wind, a fragile net of light floating over this graceful island. Time has stopped; the day collapses into these few moments.

More than 300 years have come and gone since Rau last ate the Sun over this tropical paradise. Rau is a demon who, according to one story, managed to crash a party of gods by disguising himself; he got one swallow of the elixir of eternal life before Surya (Sun) and Candra (Moon) pointed the phony out to Wisnu, who promptly decapitated the demon. Now Rau's immortal head periodically gets revenge by swallowing the tattlers, but since he has no body Surya and Candra always soon reappear, exiting out of his neck. Traditionally, Indonesians have assisted this process — men shout and women cry shrilly while they bang on various noisemakers. Now they know better, and do this only during "native shows" put on for tourists. But it was perhaps some such ancient and atavistic awe which led a police car to race by us on the completely deserted road, lights flashing and sirens screaming, not once but twice during the five brief minutes of totality. Paulus had a more playful explanation: "It reminds me of my boxer dog named Peggy that runs here and there happily after being released from her cage."

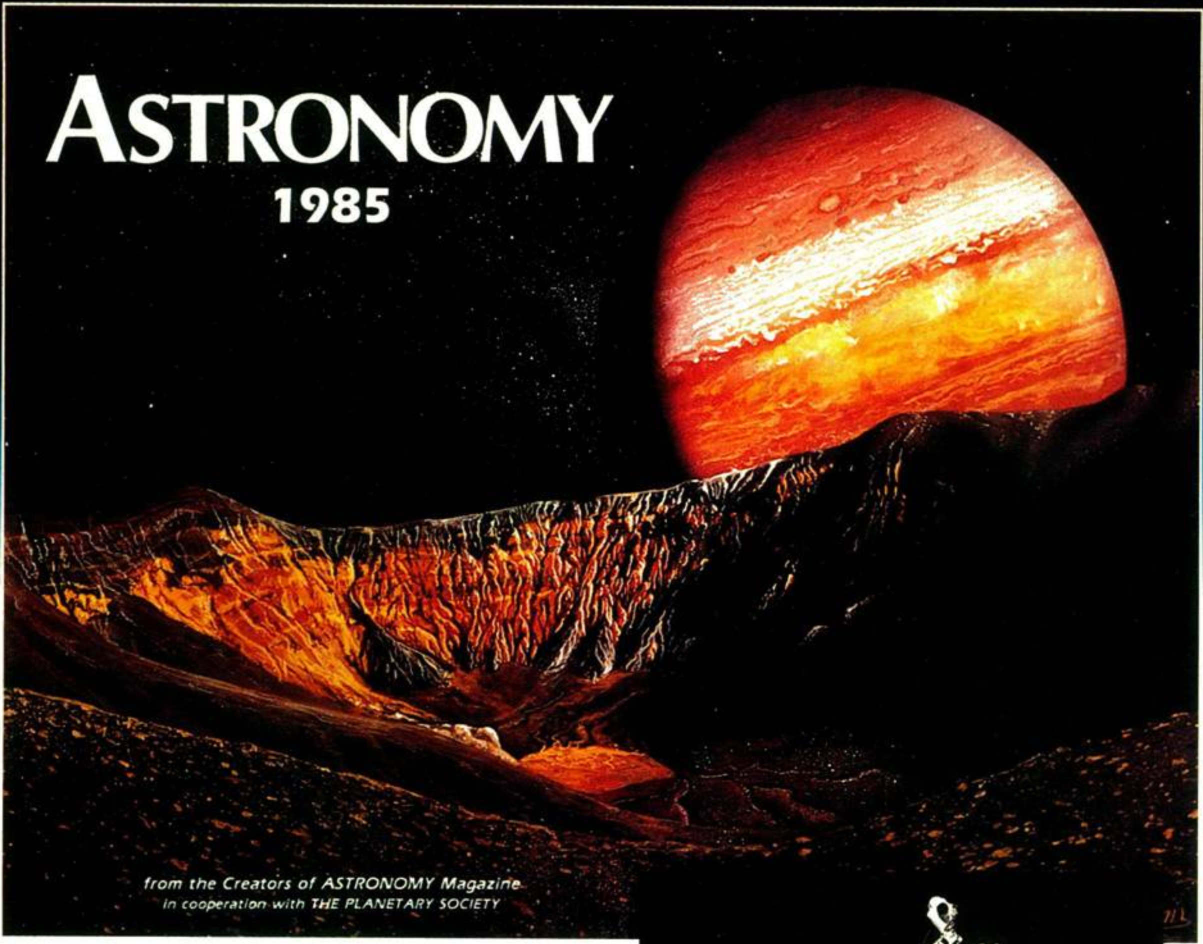
Whatever the reason for the police racket, the cacophony worked too well — as the Sun slipped inexorably out of Rau's throat. Totality was over as gently and quietly and solemnly as it had begun. We couldn't believe it — it seemed to pass more quickly than the much shorter one in Oregon. And it had never occurred to us that two total solar eclipses could be so different, each seeming to mirror the very land over which it passed — one a steamroller, the other quiet and respectful. We had been witness not to some disembodied mathematical phenomenon of celestial mechanics but to an astronomical event seemingly bound to the place over which it occurred. As soon as totality concluded and partiality resumed, the entire island of Java woke up — traffic choked the streets, children ran around the fields, bicycles and baskets were put back into action. We must have shared the same impulse — totality done, we left within half an hour for other adventures.

In one of the books on Indonesia we consulted for our trip, we found this sage advice: "It's possible to see a little of Java in the sublime detachment of air-conditioned splendour. But it is impossible to enjoy the magnetism of its landscape and people, its culture and history, without a certain amount of discomfort." Astronomers have sometimes put up with great discomfort in order to experience the thrills of stargazing. Why not, then, in order to learn the ways of fellow human beings, and most especially when one can do so while sharing with them the finest astronomical show available. Why weren't there the expected hundreds of thousands visiting Java and feasting on the solar spectacle? Expense? Perhaps, but the over-priced tours shouldn't have fooled anyone. Fear? Well, if we can't enjoy the different ways of members of our own species what are we going to do when we encounter some sentient beings from Vega or Epsilon Eridani! Inconvenience? The painful efforts made by millions of American campers, backpackers, bicyclists, sky-divers, spelunkers, mountain climbers, scuba divers, off-road enthusiasts, and others, seem to belie that.

We frankly don't understand it. We don't understand why tens of thousands of middle-class Americans weren't streaming to Java for much less than they spend on their astronomical equipment or a vacation to San Diego. The financial secret is to go to those total eclipses near major routes of travel; by avoiding tours, one can find bargain air fares and stay in inexpensive native hotels.

No matter. Perhaps next time. All we know is that the eclipse happened and it was characteristically Javanese and we saw it. Who knows what new solar eclipse wonders await us back in Indonesia in 1988 west of Krakatau in the jungles of Sumatra, or in 1991 on the mile-high plains of central Mexico, populated by the present descendants and the departed spirits of the great Aztec empire. When that narrow path opens up once again on the land, we'll try to be there, for a total solar eclipse is a visit to a city where ancient gods still live in the center of a spectacular darkness. There is nothing else like it on the planet.

— Stephanie and John Mood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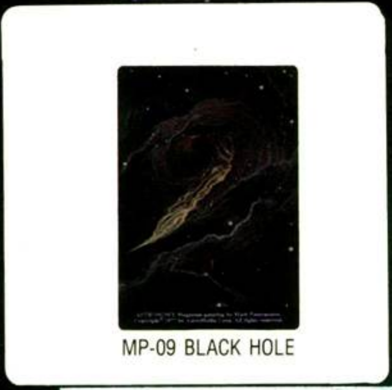

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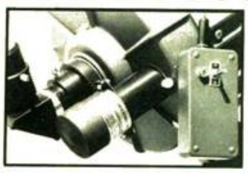

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ASTRONOMY
In Focus

Scouting the Pup

Sir / I live in the Crystal River valley in Western Colorado and have a Newtonian telescope whose 8-inch f/6.3 mirror I ground. At an elevation of 7300 feet, our observing is excellent as there is no light or industrial pollution, but the seeing varies with atmospheric conditions and, of course, temperature.

During the dark of the Moon last March, the brilliance of Sirius caught my attention. I had read that it was possible, under ideal circumstances, to occasionally glimpse "the Pup" (Sirius B) with an 8-inch. I'd last seen it during childhood, some time between 1925 and 1930, at Northwestern University's Dearborn Observatory. (The lens in that telescope, incidentally, is the one through which Alvan Clark discovered the Pup during the Civil War.)

When I put my telescope on Sirius, I was quite dumbfounded — the Pup was there! Hesitant to confirm my sighting (for it was touching Sirius) and afraid that I might simply be seeing what I wanted to see, I called my wife outside. I explained to her about the star and the possibility of seeing it, although the odds were against it. But she saw it instantly. I asked her what position it was in and when she said 5 o'clock, I was rather certain that was it. We tried again the next night and found it in the same way. The following night we had guests, one of whom thought he saw it and another who couldn't.

Imagine my delight when the July issue arrived with Barry Parker's article on "Those Amazing White Dwarfs." The chart on page 21 shows the Pup at 11:00 o'clock and, given the usual inversion by the telescope's optics, I had clearly spotted the Pup at 5:00 o'clock — just where it was supposed to be!

This pleased me greatly, for not only did it confirm the quality of my hand-ground 8-inch mirror, but far more important, I had had cataract surgery for my right eye with a plastic lens implant last October. Both my mirror and my "new" right eye passed their visual acuity tests with flying colors!

John D. Lawyer
Carbondale, CO

More on Starlight Scopes

Sir / In 1980 I attended a star party hosted by the Texas Astronomical Society as part of the Astronomical League's national meeting in Dallas. Held at one of their favorite observing sites a couple of hours from center city, I had a chance to view through a military-type starlight scope mounted on an 8-inch SCT. Observing Coma Berenices low in the west, I could count 22 galaxies in one field! Their appearance was somewhat strange, as they seemed to glisten and sparkle, but the experience was certainly rare.

So was the price: we were told that it was more than $7,000!

Robert R. Young
Harrisburg, PA

Occultation Update

Sir / In "Chasing Moon Shadows" (October issue), one of the expedition organizers was inadvertently left off the list. He is Ken Kelly, 19209 Mapleview, Detroit, MI 48205, (313) 839-7250. The November 27th graze of 60 Sagittarii passes near Detroit, and anyone who wants to get in on this expedition should contact Ken.

Also, the October 30th event involves the star ZC 2848 (the table lists the name correctly). And the November 12th track for 139 Tauri should have an "A" at its western end.

David Dunham
Silver Spring, MD

Old Comets

Sir / I'm writing in regard to the identity of the 19th century comet alluded to by Paul Casdorph in the November 1983 In Focus, and further discussed by Michael Ferrio in the August issue.

Almost certainly, Mr. Ferrio's identification is incorrect since Comet Tempel (1859b) never became brighter than fourth or fifth magnitude. Elijah Avey's reference to a "great comet that flamed across the heavens" hardly fits such an insignificant object as Tempel's comet.

A far better candidate was Donati's comet of the previous autumn (September and October 1858). Reaching zero magnitude and displaying a magnificent 40° tail, it made a slow stately passage across the western evening sky, and must have left a profound impression on the general populace for years following its apparition. Unquestionably, it is to this object (appearing almost precisely a year before the John Brown raid on Harper's Ferry) that Mr. Avery referred in his book.

John E. Bortle
Stormville, NY

Editor's note: Donati's comet can be discerned in the painting "Pegwell Bay, Kent, a Recollection of October 5, 1858" done in 1859 by William Dyce, a Scottish fore-runner of the Pre-Raphaelite school.

Another True Confession

Sir / Around the 15th of every month, I receive my ASTRONOMY magazine and it's my habit to read Forum first. Ken Fulton's article ("A True Confession," July 1984) really touched something inside of me.

Mr. Fulton's opening paragraphs sounded like the man was a self-centered, egotistical snob — which really put me off — but as I continued to read, I realized I could not have been further from the truth. Then I started to agree with him.

When I reached the part about Mr. Fulton's friend, I felt sorry for him, but as I read further, I no longer felt sorry for him. Instead, I was ashamed of myself. A man with that much drive and determination reminds me of the great astronomer Milton Humason, who started off as a mule driver for the observatory and eventually became one of the world's great astronomers. Although Mr. Fulton's friend will never reach the same plateau as Humason, he opened up the eyes of at least two people — Fulton and myself — for which I am grateful.

Thomas R. Hartnett
Johnstown, PA

Burst Balloon

Sir / Has anyone, in a moment of choicest triumph, ever thrown a wrench into your gears? This happened to me recently and I think the story is worth telling.

Several months ago, I (like many of ASTRONOMY's readers) sat in awe watching astronaut George Nelson float over to the Solar Max Satellite.

"This is fantastic," I said to my wife. "Can you believe this?"

My wife, fussing over some dusting and partially obstructing my view of the tube, said "Hmmpf."

Taken aback at her apparent lack of understanding of the history that was literally over our heads, I said, "Just what do you mean, hmmpf?"

"Big deal. That's what I meant."

I sat, slack-jawed.

Continuing on, she said, "We've been to the Moon and you call that fantastic? Hmmpf."

What could I say? My balloon was burst. She was dead right.

So you can have your space trucks, 300-mile orbits, and spider web experiments. I'll take Saturn Vs and missions to other worlds, anytime. Willy Ley and Wernher von Braun, we owe you an apology — an apology for backing up.

Norman Morrison
Oxford, AL

Round-offs in SUNNY.BAS

Sir / Many programmers do not know of a round-off problem that occurs in most versions of BASIC. It may occur in SUNNY.BAS (April 1984, ASTRONOMY), and produces an error too large to ignore. In entering the values for latitude and longitude as decimal values, the number is often rounded slightly downward by the computer because the exact fraction of a degree is not expressible as a binary fraction. This would have a negligible effect on the calculations in that the program converts from minutes and seconds to decimal fractions of a radian. The result is usually a 40-second-of-arc error in the values of variables E and F.

To see how this happens, let's follow through the first sample run given in the article. The latitude is entered as 43.04, meaning 43 degrees and 4 minutes. Because of the impossibility of expressing 0.04 exactly as a binary number, the value of the variable Z after statement 284 is actually about 43.03999997 — give or take a bit depending on your particular computer. At statement 462, Z is set to 3.999997, and in the following statement Y is set to 3. The Z now becomes 99.9997. At this point, the values of X, Y, and Z should contain the degrees, minutes, and seconds (43,4, and 0, respectively), but actually contain 43, 3, and 99.9997. This is converted to the radian equivalent of 44 degrees, 4 minutes, and 39.9997 seconds — a 40 arc-second error.

Although this will make little difference in the time of sunrise, it can be significant in other astronomical calculations. The easiest way to avoid this problem is to add one-half second or so to the absolute value of all numbers converted by the subroutine. In this case, statement 460 should be replaced by the following two statements:

```
460 LET Z = Z + 5.E - 5
461 LET X = INT(Z)
```

Donald S. Lynn
Fountain Valley, CA

— In programming here, we prefer to enter hours or degrees with their minutes and seconds as strings. We then extract the values of the appropriate digits. This makes the data easier for humans to type and to read.

Ooops!

On pages 76 and 77 of the October issue, the M-16 photo was taken by Jack Newton.

Behind the Scenes

Scopes for Kids

Last year, while shopping for a small computer for my parents, I went to a large toy store. The store had great prices on computers, and I found what I was looking for right away. So out of curiosity I went over to the "science" section to see what telescopes kids could expect from "Santa" this year.

What I saw totally appalled me.

They were selling things that looked like telescopes. They had price tags like telescopes — between $60 and $200 — but they weren't telescopes. The store was selling cardboard and plastic *imitations* of telescopes.

They came with claims of high magnification. They had 30mm diameter plastic lenses mounted in 75mm diameter tubes. They had pedestal mounts made of cardboard. And they had flashy vinyl and silver decals to make them look like real telescopes.

The people who ran the store probably had no idea what they were selling — the sales clerks I questioned most certainly did not. And there's little that can be done because selling cardboard imitations of telescopes isn't against any law. But I do feel sorry for the kids who get them.

Imagine that you're ten again. You got a telescope for Christmas. Its big shiny box says "telescope" all over it, with color pictures of the Orion Nebula, Saturn, the Moon, and a big color picture of smiling kids looking through it. All that neat stuff, and now you're going to see it. Oh boy!

But when you try to use the telescope, you can't see anything. It won't stay up. It won't point. You don't know where to look. In the end you give up, beaten, frustrated, sure that the whole thing is your fault.

So, should you find yourself in the market for a telescope, or when people who know that you're an amateur astronomer ask your advice, watch out! Check out a few toy stores yourself, and if they deserve it, warn others about their telescopes.

Now about that gift: if you're short on time, give a constellation book instead. But promise a telescope when the *two of you* have learned the constellations. Spend some time — meet Orion the Hunter, Leo the Lion, and the Big Dipper. Then take your time and research the purchase together. Finally, when you know you're ready, order a modest instrument with a steady mount. You'll never regret it. Either of you.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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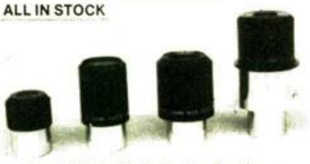

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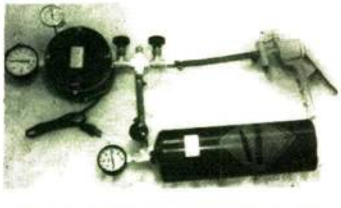

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Television in Amateur Astronomy, Part 2

by

Peter Manly

For this view of the Orion Nebula (M-42), we used an 8-inch SCT at f/5 and an RCA TC2055/U Ultracon black and white camera coupled to a Litton 841 image intensifier. All photos by the author.

Last month we examined some television systems and described the specific equipment they require. This month, we'll look at some typical observing applications.

The most obvious use for TV in amateur astronomy is casual viewing and public education at star parties. While a TV monitor never yields as crisp an image as you get through a telescope, it does allow several people to look at the image at the same time. This is no trivial matter — as anyone who's run a telescope at a star party can testify.

TV also makes it easier to point out features — a crater on the Moon, for instance — than it is to tell someone at the eyepiece to "look for the little crater next to the mountain by the valley running through the larger crater."

And don't forget cloudy nights. The giant, well-publicized star party that got clouded out would not have been such a total loss if video tapes of last week's clear skies had been available.

Also, remember that some people who are not used to looking through eyepieces will give up, rather than look harder. These same people, however, will gladly and willingly look at a TV set. Children are especially TV-oriented — a sad fact — and seem to relate more easily to information presented on a screen than seen directly.

Finally, TV often can get the local news media interested in your astronomy club. Our club has received free publicity from the local TV stations simply by supplying them with live video or tapes of interesting events such as lunar eclipses, meteor showers, and comet apparitions. While such coverage seldom makes headlines, it often turns up in the "Science Today" segments of the evening news.

Moons and Planets

One of the easiest objects to view, and probably the best starting point, is the Moon. Using a telecompressor or tele-extender on an 8-inch Schmidt-Cassegrain telescope, for example, you can observe the Moon at f/5, f/10, or f/20, with each magnification yielding different views. The Moon is very popular at star parties, and it is easy to line up and focus on. If you observe with a color camera, the Moon's surface colors are much more visible than when seen with an ordinary eyepiece. But be careful to correct the color balance, or you'll be fielding endless questions about green cheese!

Most planets are bright enough to observe without using an image intensifier. Although the resolution of the system is generally less than what you'd get if viewing directly, it's worth recording the planets on nights of intermittent good seeing. Occasional moments when the seeing is excellent will produce short segments of good tape that can be viewed repeatedly.

If you use sufficient aperture (14 inches or more), TV can record events such as eclipses of jovian moons, although the dark shadows of the moons as they transit the surface of the planet will be difficult to see. In recent months, the Red Spot has had rather low contrast. Playing with the color balance can give the Red Spot more contrast, but this doesn't always work, so you won't get regularly repeatable results.

At our club, we find that video tapes showing the phases of Venus as it passes inferior conjunction are helpful for teaching beginners how the telescopic appearance of this planet changes. Mars has not had a favorable opposition since we started operating our high-resolution TV system, but I imagine that a stock of tape segments collected over a good apparition would help explain that planet, too. With a little skill, someone could put together a marvelous multi-media production that would intersperse telescopic views of planets with spacecraft images.

Keeping an Eye on Ol' Sol

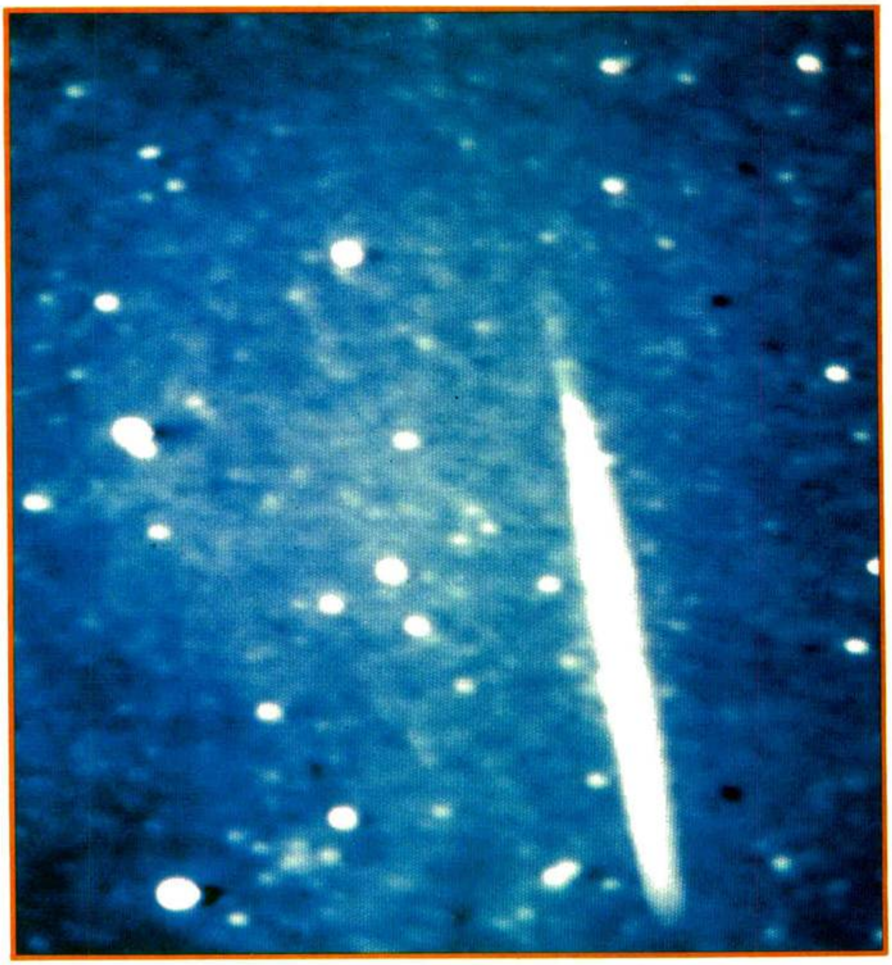
The Sun is an interesting object in most telescopes, but viewing it with a TV camera calls for a few more preparations than usual observing. The filters normally used for visual observing are not dense enough for most TV cameras if you attach the camera directly to the telescope. This is because the iris — used to control incoming light — is usually in the lens, which is removed when the camera is attached to the telescope.

To compensate, I place several neutral density filters just in front of the TV camera, in addition to the normal solar filter over the scope's front aperture. These filters are easily installed in the coupling between the camera and the telescope. Since the camera is an expensive item, start with more filters than you might possibly need, then remove them one by one until you reach the proper signal level.

Unfortunately, most cameras can't indicate they're receiving "too much light" as they can when there's not enough. Therefore, the easiest way to determine the optimum signal level is to watch the video output on an oscilloscope while you remove the filters. When you reach the point where removing a filter does not increase the signal level, put that filter back on the camera and you're set.

An alternate method is to project the image of the Sun onto a white card at the back of the telescope and point the regular TV lens at the card. This is perfectly safe, but usually requires a lot of mechanical fiddling to get the telescope, projection card, and camera all lined up.

When you observe in the daytime, take care that the camera, monitor, and video tape recorder don't bake. For sales appeal, these items are often colored matt black, making them highly-efficient light absorbers. A few white cardboard sunshades will alleviate the heat problem. The only other difficulty you'll encounter is that most monitors perform poorly in direct sunlight, so either shade the screen or put the monitor in a dark shady place.



This sporadic was caught during the 1983 Perseid shower. Again, we used the RCA TC2055/U and the Litton 841 intensifier, but chose a 12.5mm f/1.3 lens to get a wide field of view. The image field lies in the Cygnus region of the Milky Way.

Although the resolution is degraded relative to conventional observing, there are intriguing transient solar phenomena — such as flares — which are easy to record. You'll need some extra equipment, but there is nothing difficult about observing flares and prominences with an Hα filter (see "Shooting the Sun in Hydrogen-Alpha," ASTRONOMY, July 1983).

Because TV is an excellent means of recording changing events, it's great for solar eclipses, too. TV can record the exact moment when Baily's beads form or disappear, and you can also record contact times to refine eclipse shadow predictions. During the annular solar eclipse last May, many observers across North America used TV to record and preserve the fast-moving event for repeated viewing.

The Starry Sky

With an 8-inch SCT, ordinary TV cameras can see stars down to only about visual magnitude 5. Most sky scenes, therefore, have but one or two stars in them. Aside from some bright, colorful, and widely-spaced double stars such as Albireo, there just isn't much interesting stuff to look at most nights.

But by adding an image intensifier, the lower limit drops to about magnitude 12, and the number of stars in the field of view increases greatly. Open clusters such as the Double Cluster or the Pleiades, become good subjects. Both of these are so large that they spill out of the field of view, with only part of the Pleiades or half the Double Cluster visible in a single frame.

With longer focal lengths, you can measure the position angles and separations of double stars. Be careful to keep the scan size on the tube faceplate constant, though, or you'll be recording spurious variations. Most consumer-grade cameras are not well compensated electrically, and I suspect that the scanning raster size varies with temperature as well. Solid-state CCD or CID cameras have a constant raster size because the "raster" is fixed when the detector chip is made.

Unfortunately, image intensifiers do not reproduce star colors. Most image intensifiers do, however, have an extended red response with considerable sensitivity in the near-infrared — a side-effect of their military origins. With one model, this near-infrared response is so pronounced that Betelgeuse comes out as the brightest star in the sky! Some intensifiers also have a slightly greater blue response, but not usually so pronounced.

With all cameras except the SIT type, observing extended deep-sky objects — nebulae and galaxies — is impossible unless you have an image intensifier. TV cameras are much better at detecting point sources than areas, because a TV camera operates by displaying the contrast between adjacent picture elements. Since most deep-sky objects have very low contrast when compared to even very faint stars, un-intensified TV systems record them poorly.

To understand why, let's assume that a TV system can resolve one arc-second per picture element. Given this, even a 12th magnitude star in typically light-polluted skies will still be four magnitudes brighter per picture element than the sky background. Bright objects, such as the Andromeda Galaxy, are only twice as bright per picture element as the background and easily disappear into the "noise." Despite this, you can still view most of the Messier objects if you pick the proper aperture and focal length for your telescope, and observe under sufficiently dark skies.

When our club initially considered using TV for amateur astronomy several years ago, the first idea was to make an autotracker for astrophotography — why should a human have to do all that tedious guiding, right? We calculated that a low-resolution CID camera with an image 128 by 128 pixels could be hooked up to a drive corrector and a little digital logic. I'm not sure how it happened, but by the time we got a couple of these things running, the focus of our interest had shifted away from astrophotography to the TV technology itself!

Bagging Big-Game Data

Up to now, we've been exploring essentially casual uses for TV. But there are also ways to use video for providing more than just entertainment.

For example, we observed the 1983 Perseid meteor shower with a Litton model 841 image intensifier and an RCA TC2055/U camera. To get a wide field of view, we used a 12.5mm focal length, f/1.3 objective lens rather than a telescope. The resulting 20° by 30° field of view showed a fairly good portion of sky and displayed stars down to about magnitude 6. Over three hours' observing time, we caught 70 meteors and recorded them on tape.

Considering the TV's field of view, our system worked pretty well — detecting several meteors missed by naked-eye observers at the same site. From the tape, we plotted the meteors' exact trajectories to separate Perseids from sporadics. We also found four meteors that may belong to the Upsilon Pegasid shower, which peaks somewhat earlier in August. For the 1983 Orionid shower, we stationed two cameras several kilometers apart for triangulating on the meteor paths to determine their height. Unfortunately, all we recorded were the bottoms of clouds, but we'll repeat this experiment again some other time.

The only real problem with this kind of observing is the long, exhausting hours you must spend reviewing the taped data. It takes even more time to plot the meteor tracks and estimate their brightnesses from the surrounding stars. We currently do this by hand, but computers may soon come to our rescue.

Since a TV camera slices time into $^1/_{30}$-second pieces, it's ideal for observing rapid, transient events such as occultations. Television has been used for several years by the International Occultation Timing Association (IOTA) to record stars which skim past the edge of the Moon and are briefly occulted by individual lunar mountains. (See "Chasing Moon Shadows," ASTRONOMY, October 1984.)

Timing the complex sequence of events as stars disappear and reappear leads astronomers to a better understanding of the lunar limb profile, and provides information about the position and motions of the Moon with respect to the stars. IOTA observers also use TV to watch asteroids pass in front of stars, and time the star's disappearance and reappearance. This data can be used to construct a profile of the asteroid to reveal its size and shape.

In the past, most occultation data have come from visual observers looking into a telescope's eyepiece, or by photometers that detect the instant when a star's light blinks off and on. But there are problems: visual observers have individual reaction times for recording events — and these vary widely depending on the person, the brightness of the star, the individual's fatigue level, and external distractions such as cold and wind.

Photometers are also flawed in that they usually cannot track on a star for long times while simultaneously taking data. A few multi-channel photometers can do this, but they are expensive and complex to use. TV allows observers to record the event and make precise timings, provided you have recorded a time signal (such as radio station WWV) along with the video.

Portable TV equipment easily lends itself to observing occultations at remote sites. In some cases, a little TV has eliminated a lot of telescope. For one occultation we observed, the addition of a two-pound intensifier and a five-pound lens saved us shipping expenses on a 50-pound telescope. This makes a real difference in air-freight charges! At present, only a few occultation observers use TV, but the number is certain to increase in years to come.

Satellite Tracking

Recently, a fellow amateur astronomer asked if we could track an artificial satellite launched by the Soviets. He was curious to see if the brightness of the object varied. If it did, this was evidence the satellite was tumbling; while if the brightness remained constant, the "bird" was probably stabilized. He supplied rough coordinates and times for observing the satellite. Using a TC2055/U camera mounted on a common alt/az tripod with an 841 intensifier on a 70mm, f/1.5 lens, we were able to spot and track the satellite manually while recording its brightness. (It *was* stabilized, by the way.)

This particular object was in low Earth orbit, but satellites in higher orbits can also be observed. We used an 8-inch SCT to spot a few large communications satellites in synchronous orbit 36,000 kilometers away. Some are well within the magnitude 12 limit for an intensified camera and can be detected by their slow motion with respect to the stars. Since these satellites are in synchronous orbit, they don't appear to move when you turn off the telescope drive.

* * *

To sum it up, TV has many uses in amateur astronomy — from casual observing to public education to serious data collection. Advances in equipment sensitivity, resolution, size, and cost have brought this technology down to the point where, although expensive, it's not totally out of the question. If we can judge by past developments in electronics, the future of video astronomy looks very exciting indeed!

Peter Manly is an electronics engineer living in the Phoenix area. He has been an amateur astronomer for the past 32 years and built his first TV-telescope rig in 1972.

What's Available Today

I was disappointed when I went to survey the camera market recently. All the new cameras have non-removable lenses and are unsuitable for astronomy.

In addition, on one "idiot-proof" camera we tried using projection from the intensifier. It gave a scene that was mostly black with a reasonably good image of an open cluster. The automatic circuitry in the camera, however, measured the average scene brightness, turned on an indicator which said we didn't have enough light, and then informed the video tape recorder that the scene was unsuitable. The microprocessor-controlled tape recorder, wishing to save us the embarrassment and expense of wasting tape, *would not allow us to record!* The most useful thing you can do with a system like that is put it under the wheel of your car when you park on a hill.

At any rate, the only two-color cameras on the market with removable lenses are the Panasonic PK3150 and the RCA CC011, both of which are Newvicon types. The only monochrome camera with a removable lens and an Ultricon tube is the RCA TC2055. All others are made for bank surveillance and come with non-removable lenses and remote controls.

I have not mentioned the SIT cameras in this survey because their starting price is $14,000, not including taxes, license, or dealer preparation. There are several solid-state chip manufacturers (Fairchild, Texas Instruments, Reticon, etc.), but none of these manufacture a solid-state camera with a removable lens other than the General Electric TAN2000 series. RCA has promised to come out with a solid-state surveillance camera "soon," but I have yet to see it.

Addresses of intensifier manufacturers and dealers:

Amperex Electronic Corp.
Electro-Optical Devices Division
Slatersville, RI 02876

Electrophysics Corp.
48 Spruce St.
Nutley, NJ 07110

FJW Industries
215 E. Prospect Ave.
Mt. Prospect, IL 60056

ITT Electro-Optical
Products Division
7635 Plantation Rd.
Roanoke, VA 24019

Litton Industries
Electron Tube Division
Electro-Optics Department
1215 South 52nd St.
Tempe, AZ 85281

NI-TEC Inc.
Marketing Dept.
5600 W. Jarvis Ave.
Niles, IL 60648

RCA Solid State Division
Electro Optics and Devices
Lancaster, PA 17604

Varian LSE Division
601 California Ave.
Palo Alto, CA 94303

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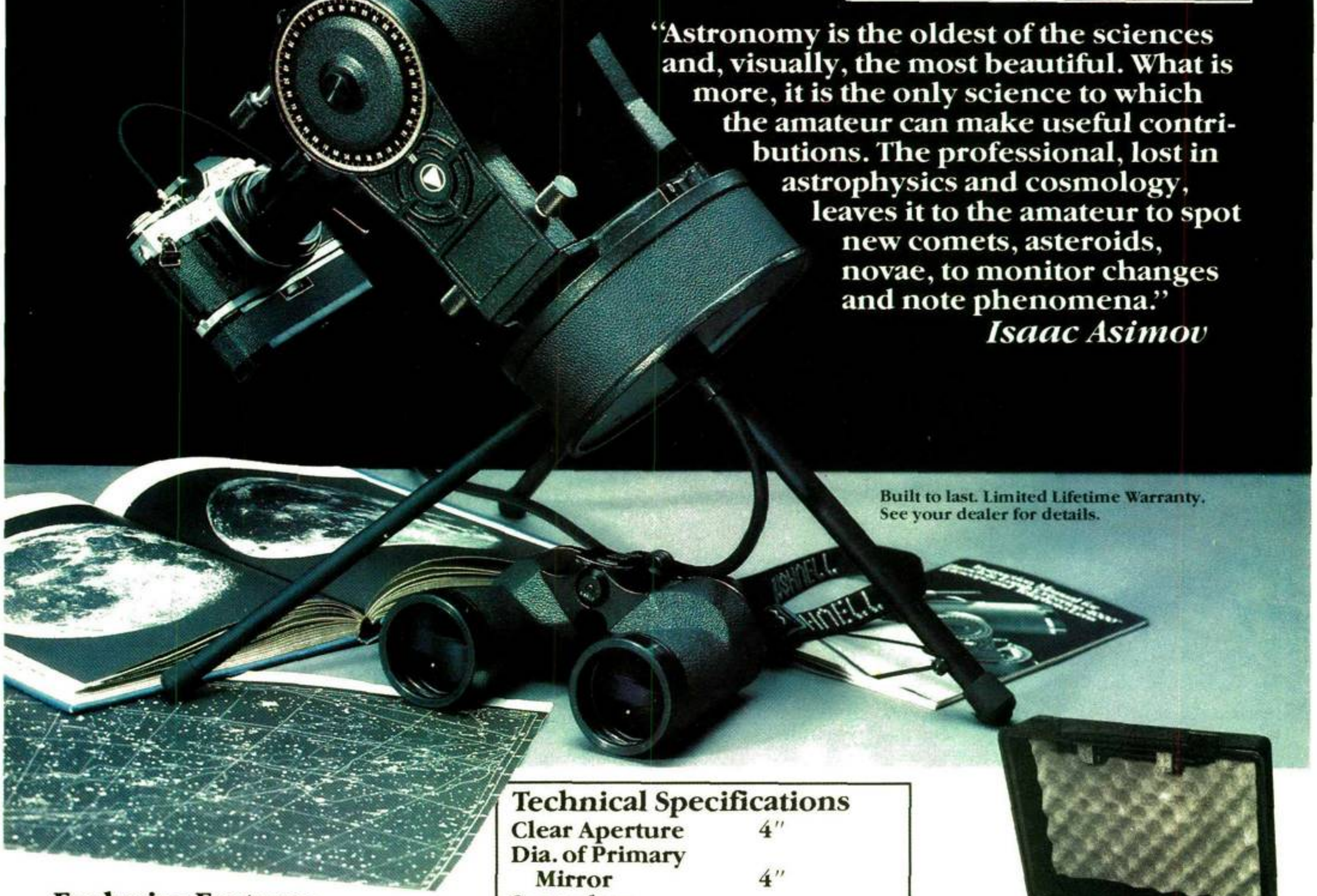

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ASTRONOMY
Reviews

Superstars: How Stellar Explosions Shape the Destiny of Our Universe

David H. Clark
216 pages, hardcover, $17.95
McGraw-Hill (1984)

They burst into brilliance, sending beacons flashing far across the cosmos. Though one of the most awesome phenomena known, they are statistically common, occurring at the rate of 10 every second somewhere in the known universe. They have been called "visiting stars," "new stars," and "guest stars," but today, these colossal stellar explosions are called supernovae. They are indeed "superstars."

British astrophysicist David Clark has produced a clear, fascinating, and highly readable account of what is presently known and conjectured about supernovae. This nontechnical book is well-written — though somewhat rambling in places — yet it is clearly the result of much extensive research, especially in the area of archeoastronomy.

Opening with a discussion of distance and the time scale of the universe, Clark briefly describes stellar formation and evolution. Labeling supernovae "one of nature's greatest spectacles," Clark delves into their characteristics with enthusiasm. He poses several intriguing questions: Was a supernova responsible for creation of the solar system? Might one have caused the Earth's ice ages? Can the demise of the dinosaurs be attributed to a nearby supernova sometime in the fairly recent past? Was the star of Bethlehem in reality a supernova? What effects will these mighty events have on the future of mankind?

Pre-telescopic observations, of great importance in compiling a book such as *Superstars*, are nonetheless ambiguous in many instances and of questionable accuracy in others. Wisely, Clark judges early written records with a conservative skepticism, freely pointing out areas of uncertainty and possible bias.

The earliest Chinese records, extant from about 200 BC, point to definite sightings of seven supernovae, each confirmed by modern radio astronomy. According to Clark, the supernova of 1006 was probably the most spectacular ever recorded. Records from the Middle East, the Orient, and Europe leave little doubt that it attained about −9 magnitude! It remained visible for several years before fading from view.

In his chapter 7, "A Superstar is Born," he turns to a more familiar supernova — that which produced the Crab Nebula. This wasn't a hugely spectacular event even at its brightest — it approximately equalled the brilliance of Venus — but it is so intensively studied because it can be observed in detail across a wide range of frequencies.

On the average one supernova should occur within our Milky Way Galaxy every 200 years or so. Further, one should occur near enough to the Earth to rival a Quarter Moon's brilliance about once in 10,000 years. The energy released in a typical supernova is estimated by Clark to equal that of 10 billion billion billion (10^{28}) 10-megaton hydrogen bombs. The intrinsic brightness of such an event would be several billion times that of the Sun. Since we are overdue for a galactic supernova, when might we expect another? And how near planet Earth?

The author surmises that a nearby supernova would immediately attack our planet's ozone layer with a massive blast of radiation right across the spectrum and that years later, as the slower-moving stellar ejecta enveloped the Earth, other catastrophic long-term effects would occur. Clark points out that a supernova near enough to influence the Earth drastically would occur in the solar neighborhood only infrequently. This, he says, has happened only 100 times since the formation of the solar system, so our threat from such a calamitous event is minimal.

The book will probably be widely read. Nearly everyone, armchair astronomer or active observer, will find it provocative and informative. It is probably the best comprehensive popular-level book dealing with supernovae. *Gail O. Clark.*

Ascent to Orbit: A Scientific Autobiography

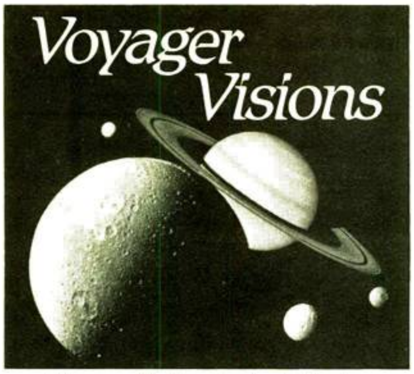
Arthur C. Clarke
226 pages, hardcover, $19.95
John Wiley (1984)

Some years ago I commented in ASTRONOMY that few people think of Arthur C. Clarke as a scientist. I've always thought this notion was unfortunate, so when I first saw *Ascent to Orbit* advertised, I practically fell over myself ordering a copy.

Well, what did I get? A lot more than I expected. In purely fiscal terms, this book has to be one of the best deals in many a year. It's beautifully bound in sewn signatures, has gold and silver printing on a cloth spine, plus excellent printing on high-quality, oversized paper — I've seen books priced three times as much that weren't half as well made. How they did it is immediately clear upon opening a copy — minimal typesetting costs. The book is literally a reprint of Clarke's scientific papers, photocopied, printed, and bound together, with brief autobiographical introductions.

The second big surprise was how little many of these papers have dated in the 40 years since most were written. The papers cover a wide spectrum. The first is a letter to the late John W. Campbell that was printed in the "Brass Tacks" column of the May 1938 *Astounding Science Fiction* (still being published under the less flamboyant title *Analog*). The letter criticized an earlier article "by an author who seemed blissfully unaware of the basic facts" of rocket propulsion. Clarke's letter is full of what might be charitably described as youthful enthusiasm: "Run back to your marbles, you Brass Tackers, or you might get hurt. This is where men are going to fight."

Next follows a number of papers on



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early radio, television, and radar theory which are extremely technical and so outdated as to be only of historical interest — which Clarke freely admits. But interspersed with these are a few of a more readable nature such as "You're on the Glide Path — I Think" from *The Aeroplane* published September 23, 1949. Despite some excessively heavy-handed humor, the essay is a fascinating description of Clarke's involvement in testing of the first ground-controlled approach radar during World War II.

Several of Clarke's semi-popular papers dealt with the future of astronomy — suprisingly accurately as it turned out. Clarke correctly predicted the importance of observations in non-visible wavelengths at a time when World War II technological developments were only beginning to make these apparent and when much of the astronomical community was scoffing at space flight.

Having worked on the development of radar and predicted its astronomical use to measure both distances and planetary surface properties, Clarke is in a good position to show us the vast, but generally ignored, impact the war had on astronomy. "My first address to the British Astronomical Association — 'The Astronomer's New Weapons' — was delivered in June 1945, while I was still in RAF uniform. Although the war in the East was still in progress (no one knew then how swiftly Luis Alverez and his colleagues would bring it to an abrupt end), much of the secrecy surrounding radar had been lifted, and I was able to talk freely about future technical developments. Many of these have indeed come true, for just about this time the foundations for radio astronomy were being laid. People like Bernard Lovell were looking wistfully at the big radar dishes that would soon be scrap metal, and wondering how they could get their hands on them."

For those who wish to learn the astronautical basics, I highly recommend the semi-technical "Principles of Rocket Flight" and "The Dynamics of Space-Flight." These subjects are not likely to be outdated in the foreseeable future, and by the time they were written (1949), Clarke had settled into his full stride as a science popularizer. Also included is a 1981 paper on "The Space Elevator: 'Thought Experiment' or Key to the Universe?"

But as always with Clarke, it is his philosophical pieces that steal the collection. A technocrat with a social conscience, Clarke has the unparalleled ability to portray things technological in a manner poetic.

Ending a November 1945 article on "The Rocket and the Future of Warfare," Clarke wrote, "Upon us, the heirs to all the past and the trustees of a future which our folly can slay before its birth, lies a responsibility no other age has ever known. If we fail in our generation, those who come after us may be too few to rebuild the world when the dust of the cities has descended and the radiation of the rocks has died away."

And in 1950: "That is the danger, the dark thundercloud that threatens the promise of the dawn. The rocket has already been the instrument of evil, and may be so again. But there is no way back into the past: the choice, as Wells once said, is the Universe — or nothing. Though men and civilizations may yearn for rest, for the Elysian dream of the Lotus Eaters, that is a desire that merges imperceptibly into death. The challenge of the great spaces between the worlds is a stupendous one; but if we fail to meet it, the story of our race will be drawing to a close. Humanity will have turned its back upon the still untrodden heights and will be descending again the long slope that stretches, across a thousand million years of time, down to the shore of the primeval sea." *Donald Robertson.*

Stonehenge Complete
Christopher Chippindale
296 pages, hardcover, $29.50
Cornell University Press (1983)

This book's subtitle reads, "Everything important, interesting, or odd that has been written or painted, discovered or imagined, about the most extraordinary ancient building in the world." That just about says it all.

Vectorial Astrometry
C.A. Murray
326 pages, hardcover, $49
Heyden and Son (1983)

This is a technical work on positional astronomy by a staff member at the Royal Greenwich Observatory in England. Obtaining highly accurate positions of stars is complicated by the motion of the Earth and solar system, so the book begins with a look at the dynamical foundations of astrometry. It also outlines coordinate systems in four-dimensional space, precession and nutation, Earth-based astrometry, and stellar kinematics.

A Workbook for Astronomy
Jerry Waxman
356 pages, spiral bound, no price given
Cambridge University Press (1984)

This manual offers short essays on astronomical subjects, followed by experiments that can be carried out in a classroom, outside under the stars, or inside a planetarium. The exercises cover important ideas in observational astronomy: geometry of a solar eclipse, age of the lunar surface, the Moon's diameter, distances to Cepheid variables, classification of galaxies, distance to the galactic center, spectral types of bright stars, and the scale of the solar system.

Frozen Star
George Greenstein
272 pages, hardcover, $16.95
Freundlich Books (1984)

Frozen Star is a popular-level account of pulsars and black holes. It explores many topics of modern astronomy, including radio telescopes, the nature of light, spacetime geometry, the Chandrasekhar limit, binary X-ray sources, and the nature of electromagnetic radiation. Greenstein presents his topics in storybook form, piecing together varied thoughts and experiences.

Galactic and Extragalactic Infrared Spectroscopy
M.F. Kessler and J.P. Phillips, eds.
472 pages, hardcover, no price given
D. Reidel (1984)

This book, the proceedings of the 16th ESLAB Symposium held in Toledo, Spain in 1982, deals with the physical processes that lead to spectroscopic features in the infrared and reviews the current status of observations of various infrared-emitting objects.

Diffuse Matter in Galaxies
J. Audouze, J. Lequeux, M. Levy, and A. Vidal-Madjar, eds.
262 pages, hardcover, $39.50
D. Reidel (1983)

Thanks to many new observations, we now know that the interstellar medium consists of relatively cold, dense clouds surrounded by fairly hot and tenuous gas. This book, based on papers presented at the Institut d'Etudes Scientifiques of Cargese in France, analyzes the hot, tenuous component of the interstellar medium. Topics include the structure and energy sources of the interstellar medium, its dynamics, and elements of its atomic physics, including nucleosynthesis and compositional evolution.

Causes and Effects of Changes in Stratospheric Ozone: Update 1983
254 pages, paperback, $15.50
National Academy Press (1984)

This report describes the findings of recent research and the resulting improvements in scientific understanding of the causes and effects of changes in stratospheric ozone, one of a series on the subject prepared under the auspices of the National Research Council. The report is divided into two parts: Part I, "Perturbations to Stratospheric Ozone," deals with changes in the atmosphere; Part II, "Effects on the Biota," examines the effects of changes in ultraviolet radiation that would accompany changes in the total amount of O_3 above the Earth's surface.

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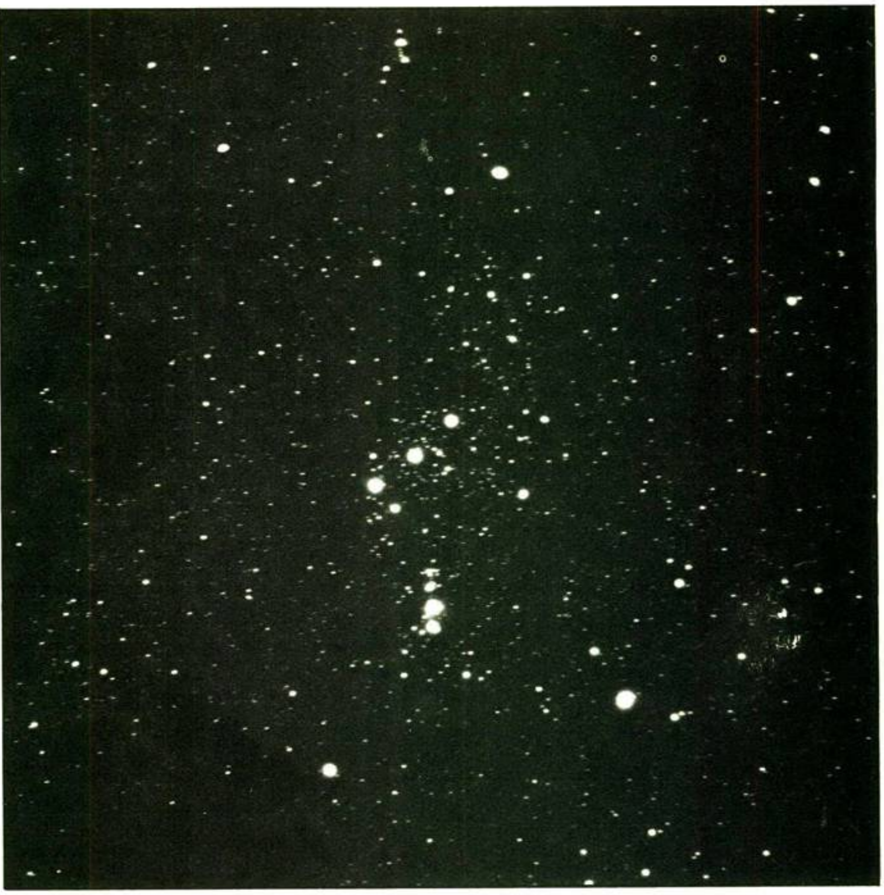
Mercury in the Morning Sky

by Fred Schaaf



Above: Orion as seen in binoculars at a dark site. Michael Clark photo (28mm lens, Tri-X, 45 seconds at f/2.8). Top right: The May 30, 1984 eclipse seen from 40 km north of Rome by Diego Meozzi (5-inch SCT, Ektachrome 64, 1/1000 second at f/10, no filter). Bottom: Aurora over Sellersburg, Indiana, March 1981. Charles Renn photo (28mm lens, ASA 100 film, 4 minutes at f/2.8).

The Wanderers

During the past three months, **Venus** became easily visible in the evening sky and engaged in some spectacular conjunctions. But it was still rather low in the southwest at sundown. This month, however, you can see Venus gain more altitude than it did in the previous three months combined.

As December opens, Venus sets almost three hours after the Sun; this will increase to more than three-and-a-half by New Year's Eve. During the month, Venus brightens noticeably and closes the gap between itself and ruddy **Mars** to less than 10°.

Venus is nearing the time of its greatest visibility — called greatest elongation — which occurs next on January 21st, 1985. The motions of Venus and Mars are such that we will have these two planets close to each other for months to come. This is an excellent time to begin a photographic record of this unusual planetary encounter. You may wish to include Jupiter in some of your photos before it leaves the evening sky and is lost in the twilight. (For photographic detail see the captions to the accompanying photos.)

By year's end, Venus will have followed Mars into Aquarius and the two will form a distinct pair in this dim section of the heavens.

Although Venus makes a wide pair with Mars at the end of December, it's much closer to **Jupiter** in the early part of the month. The sight will be anticlimactic after November's Venus-Jupiter conjunction, yet these two planets are exciting to watch whenever they are in the same region of sky. Soon to be overtaken by the Sun, Jupiter is still brighter than magnitude −1.5. The gap between sunset and Jupiter-set decreases from 2½ hours to 45 minutes during December. How long into the New Year will you be able to detect Jupiter with the naked eye and binoculars? Superior conjunction occurs on January 14th, 1985.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Mercury becomes visible to early risers during the last week of December. Although the tiny planet does not reach greatest western elongation until January 3rd, it will reach maximum elevation for viewers near 40° north latitude by December 31st. As the old year ends, Mercury rises in the southeast 1¾ hours before the Sun and is at the peak of what may be its best morning apparition of 1984. (Usually, the best morning apparition occurs in late summer or early fall.)

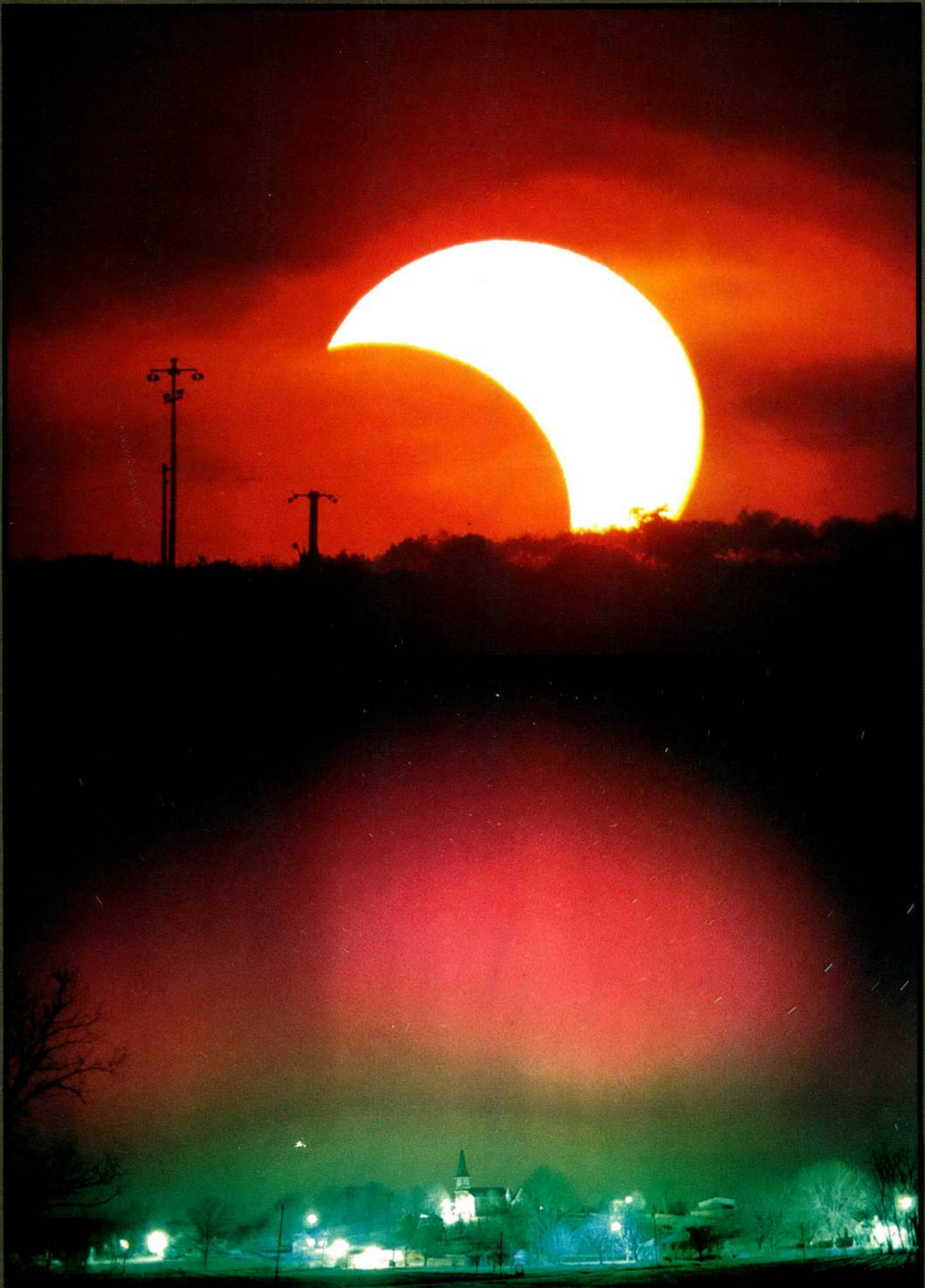
One more planet is visible as the year ends. **Saturn**, like Mercury, is a sight for early risers. Shining at only 0.7 magnitude, Saturn ends the year less than 2° south of fourth-magnitude Gamma (γ) Librae and much closer to fifth-magnitude Zeta (ζ) Librae. On the morning of December 21st, Saturn passes a mere two arc-minutes north of the 6th magnitude star 32 Librae. This occurs 36° west of the Sun, so both objects should be visible with binoculars in a good sky.

If the Last Quarter Moon didn't interfere, meteor observers would see a fine display of Geminids this month on the morning of the 14th. Instead, you'll do best to concentrate on the often ignored **Ursid meteors**. These appear to originate from the Little Dipper's bowl, and reach peak activity on the night of December 21st/22nd — the night of New Moon. The number of Ursids you can expect to see depends on your location, but after midnight at a dark suburban or rural site, about 10 to 15 meteors per hour is likely.

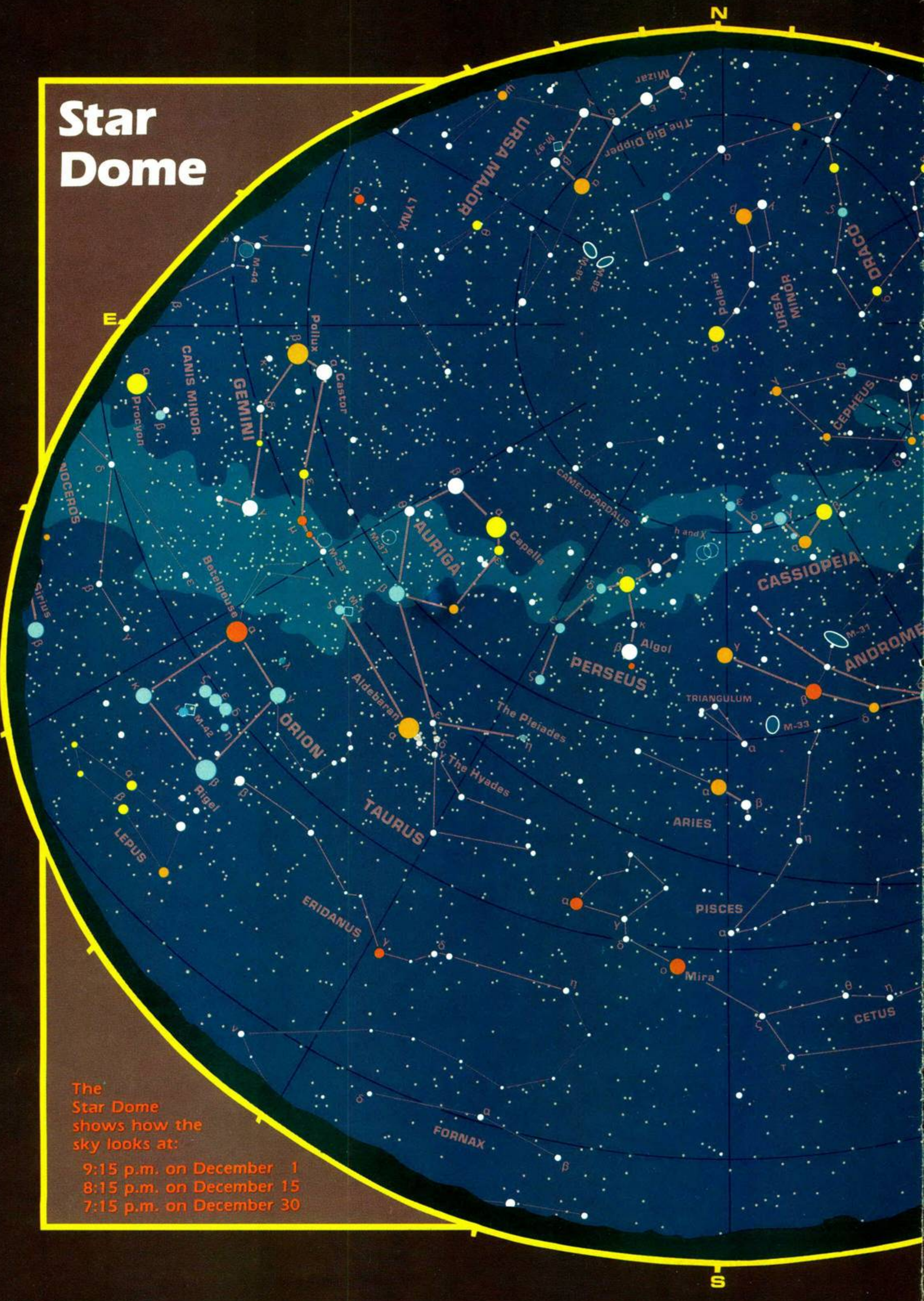
The Starry Sky

Taurus the Bull is the westernmost of the traditional winter constellations, therefore it leads the procession. Taurus has two main components — each a star cluster so superb that it could be a constellation in its own right. These two clusters are among the biggest, brightest, and closest. One of them — the **Pleiades** — appears richer to the naked eye than any stellar gathering in the sky.

Just how many naked-eye stars dwell in the Pleiades is a matter of debate. The cluster is named after the Seven Sisters of Greek mythology; but in a hazy, moonlit, or city-lit sky, you'll see only six stars here. Even on a clear night in the country, observers with average eyesight find it

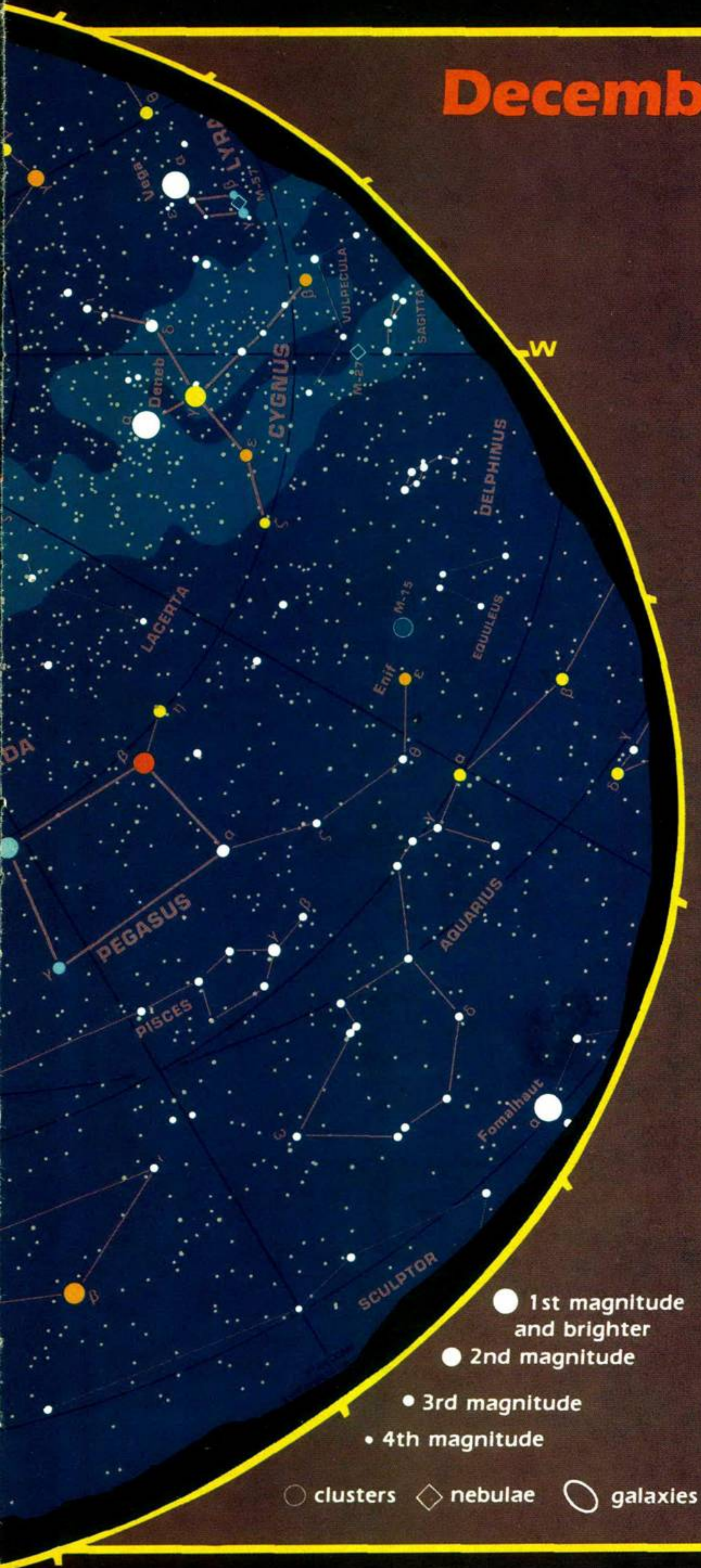


Star Dome


N
E
S
Mizar
The Big Dipper
URSA MAJOR
M-97
M-81
M-82
LYNX
M-44
Polaris
URSA MINOR
DRACO
CEPHEUS
Pollux
Castor
CANIS MINOR
Procyon
GEMINI
NOCEROS
CAMELOPARDALIS
h and χ
CASSIOPEIA
M-37
M-35
AURIGA
Capella
Betelgeuse
M-1
Sirius
M-31
ANDROMEDA
Algol
PERSEUS
TRIANGULUM
M-33
ORION
M-42
Aldebaran
The Pleiades
The Hyades
Rigel
LEPUS
TAURUS
ARIES
PISCES
ERIDANUS
Mira
CETUS
FORNAX

The Star Dome shows how the sky looks at:

9:15 p.m. on December 1
8:15 p.m. on December 15
7:15 p.m. on December 30


LYRA
Vega
M-57
VULPECULA
SAGITTA
W
Deneb
CYGNUS
M-27
DELPHINUS
LACERTA
M-15
EQUULEUS
Enif
DA
PEGASUS
AQUARIUS
PISCES
Fomalhaut
SCULPTOR
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

December Sky Almanac

2nd The Moon is farthest from Earth at 10:26 a.m. EST: 251,541 miles.

5th Uranus is in conjunction with the Sun. It switches from the evening to the morning sky, but won't be visible for a few more weeks.

8th The Moon is Full at 5:53 a.m. EST.

13th Late tonight and early tomorrow is the best time for observing the Geminid meteor shower, but the Moon will greatly interfere with viewing.

14th Mercury passes through inferior conjunction and shifts from the evening sky to the morning.

18th The Moon is closest to Earth at 4:56 a.m. EST: 228,907 miles.

21st The solstice occurs at 11:23 a.m. EST; winter begins for the northern hemisphere. Late tonight and early tomorrow morning, the Ursid meteors reach peak activity (see text).

22nd New Moon occurs at 6:47 a.m. EST. Neptune is in conjunction with the Sun. Like Uranus, it passes into the morning sky, but will remain out of sight for telescopic viewers for several weeks more.

23rd Start looking for Mercury very low in the southeast just before sunrise.

30th The Moon reaches First Quarter at 12:27 a.m. EST and is farthest from Earth at 7:16 a.m. EST: 251,240 miles.

very hard to locate more than six.

The six brightest Pleiads are brighter than magnitude 4.5, and the eighth brightest is almost a full magnitude fainter. The key seventh star, Pleione, is a variable that ranges from 5.0 to 5.5 magnitude. There is much speculation about what star is the legendary "lost Pleiad"; Pleione is the best candidate. Besides being variable, it is hard to see for another reason: it lies just five arc-minutes north of 3.8 magnitude Atlas.

Even when waves of unsettled atmospheric seeing send twinkling shivers through the Pleiades, observers with normal eyesight can perceive that the six brightest stars form a diminutive dipper with a short, straight handle. The end of the handle is Atlas, with Pleione close by. The bright stars of the bowl (in clockwise order from the beginning of the handle) are: Alcyone, Maia, Taygeta (on the top of the bowl), and Electra and Merope (on the bottom). The other named Pleiads brighter than magnitude 6.0 are Celaeno and Asterope; the latter is actually a double star and requires binoculars.

If we include 5.6 magnitude 18 Tauri, there are 10 Pleiads brighter than the naked-eye limit of 6.0, but some have counted 12 with the naked eye on the darkest rural nights and the record may be 18! Binoculars, of course, reveal dozens more, and astronomers estimate the full cluster population may run to about 500 stars.

This wonderful gathering lies slightly more than 400 light-years away, and is moving south-southeastward at an angular speed of less than one Moon-diameter every 30,000 years. The stars Pleione, Celaeno, and Asterope appear slightly fainter mainly because they are a little farther from us.

Alcyone is the most luminous Pleiad of the group. Its 3.0 apparent magnitude translates to an absolute magnitude of −2.5 — roughly 1,000 times more luminous than our Sun. Atlas, the second brightest Pleiad, has an absolute magnitude of −1.0. After this, the next six brightest Pleiads are almost identical in true brightness.

All the brightest Pleiades are members of spectral classes B6, B7, or B8 — young blue stars burning their nuclear fuel at a prodigious rate and still swathed in dusty gas. These stars spin so rapidly (just a few days per rotation) that they must be considerably oblate, and some might be

Left: The bowl of the Big Dipper shines through an aurora photographed at Newton Lake, Wyoming. Car headlights made the yellowish streak, right center. Dewey Vanderhoff photo (35mm lens, Fuji 400, 40 seconds at f/2.8). Right: Dark-floored Plato, the Alpine Valley, and part of northern Mare Imbrium on the Moon. Brian Tkachyk photo (8-inch SCT, 2 seconds, 2415 film at f/50).

belted with equatorial disks of material.

The other great cluster in Taurus, the **Hyades**, forms a triangle or V. It includes a foreground star, first magnitude **Aldebaran**, which is not a true cluster member. The Hyades cluster contains 25 stars brighter than magnitude 6.0, and 10 brighter than 4.5. None, however, are quite as bright as Alcyone, and, most importantly, the Hyades stars are spread over an area many times greater than the Pleiades. The cluster therefore does not appear nearly so rich.

Interestingly, the central area of the Hyades — its V pattern — is almost identical in true size to the dipper of the Pleiades, but since the Hyades lie more than three times closer, they appear correspondingly more spread out.

The Hyades is the closest open star cluster to us except for that in Ursa Major, which is too dispersed to be readily apparent. Like the Ursa Major group, it is accompanied by stars that appear very distant from the cluster's center yet which pursue the same general course. Strangely, whereas Aldebaran is not related to the cluster, the star **Capella** in **Auriga** the Charioteer *does* seem to be traveling with the Hyades!

Yellow Capella is now as high as Taurus and much more northerly. Southeast of Taurus is famed **Orion** and his three-starred belt. A line drawn from Aldebaran to the belt and extended as far again brings us to the brightest of all stars in the Earthly sky, **Sirius** in **Canis Major** the Great Dog.

As Sirius rises, **Perseus** — which lies north of the Pleiades — and **Cassiopeia** are close to the zenith for most readers; blue-white **Vega** in **Lyra**, the Lyre, is setting in the northwest to one side of the upright Northern Cross — Cygnus the Swan. (This year Venus also sets as Sirius rises, but in the southwest.)

Skylore

In the earliest days of some of the world's greatest cultures, the Pleiades may have been used to determine the start of a new year. In fact, the Pleiades may be useful in helping us date the beginnings of these civilizations. Ancient China, India, and Arabia all used "lunar zodiacs" — 28 stations of stars marking the Moon's nightly positions. The oldest of these zodiacs places the Pleiades as the first station. Why should it be given this distinction? The most likely answer is that this zodiac was formed at a time when precession placed the vernal equinox (the Sun's position on the first day of spring) near the Pleiades.

How long ago was this? Taurus was the first constellation of the solar zodiac when it contained the vernal equinox, from approximately 4000 B.C. to 1700 B.C. The equinox was close to the Pleiades for many centuries around 2500 B.C. Were civilizations flourishing in China and India at such an early date?

In 1924, archaeologists at the site of Mohenjo-daro in northwest India were amazed to find the remains of cities whose material cultures seemed to rival those of Sumeria and Egypt from the same period — around 2900 B.C. In China, much "ancient history" can be regarded as legendary, but records of some known historic events have been retained from as far back as 2500 B.C. The most interesting, for our context, is mention of the Pleiades in the Chinese annals for 2357 B.C. (There is evidence that some constellations, such as Taurus and Capricornus, were invented much earlier, but this mention of the Pleiades is so far the earliest definite reference to a known stellar object.)

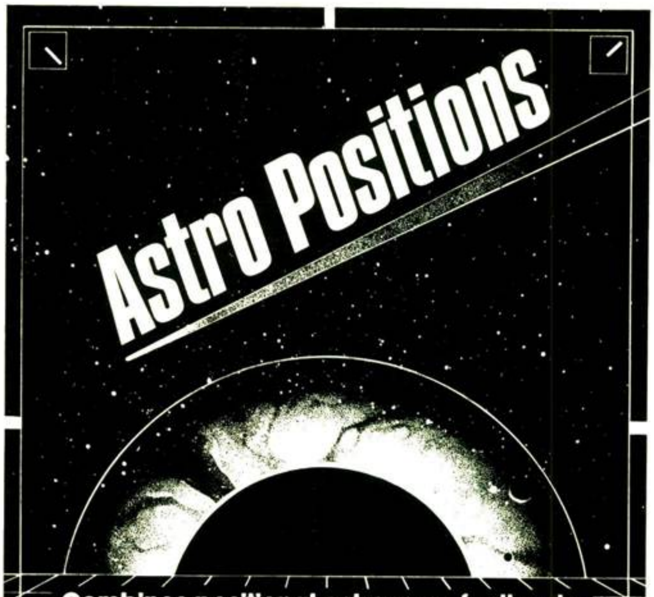
Although the Egyptian and Sumerian civilizations might have earlier origins, the first cultures in China and India possibly began to flourish in the third millennium B.C., when precession placed the Pleiades in a position of special importance. At this time, the Egyptians were infatuated with Sirius and probably started their year at its heliacal rising, which also coincided with the Nile flood.

Later, around the time of Christ, the Hindus changed their lunar zodiac. The Pleiades' position as first lunar station, or Karteek or Kartiguey — the "General of the Celestial Armies" — was replaced by a lunar station which had been 27th in the series of 28. This new leader was formed from some stars in Aries. But the original zodiac-starting position of the Pleiades was not forgotten. Al-Biruni found a reference to it in the Hermetic Books — sacred books of Egypt whose authorship was ascribed to the god Thoth, whom the Greeks called Hermes Trismegistos (see last month's column). Furthermore, the full cycle of precession, 25,784 years, eventually became known as "the Great Year of the Pleiades."

Some cultures have based their entire year on the Pleiades' positions, finding this easier to follow than the motions of the Moon or Sun. For example, the Society and Tonga Islands called the cluster Matarii, "the Little Eyes," and divided their year into two seasons, Matarii Above and Matarii Below, referring to when the cluster was above or below the horizon in the evening.

Long after the vernal equinox moved away from the Pleiades, a new reason for beginning the year in November ("the Pleiad-month") may have come into effect. Some cultures, such as the Chinese, have a festival of the dead in November, presumably because this time of year sees the death or disappearance of most flora and fauna in northern lands. For cultures concerned with nature and agriculture, what more logical end to the year than late October or early November?

Of course, the year now in secular use throughout the world ends with December — a result of ending the year when the Sun is observed to be moving north, promising the eventual return of spring.



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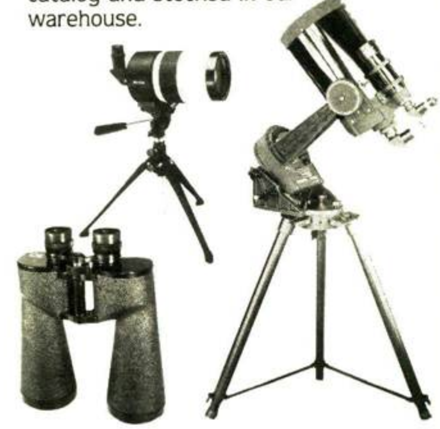

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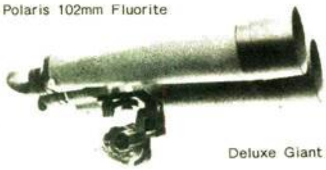

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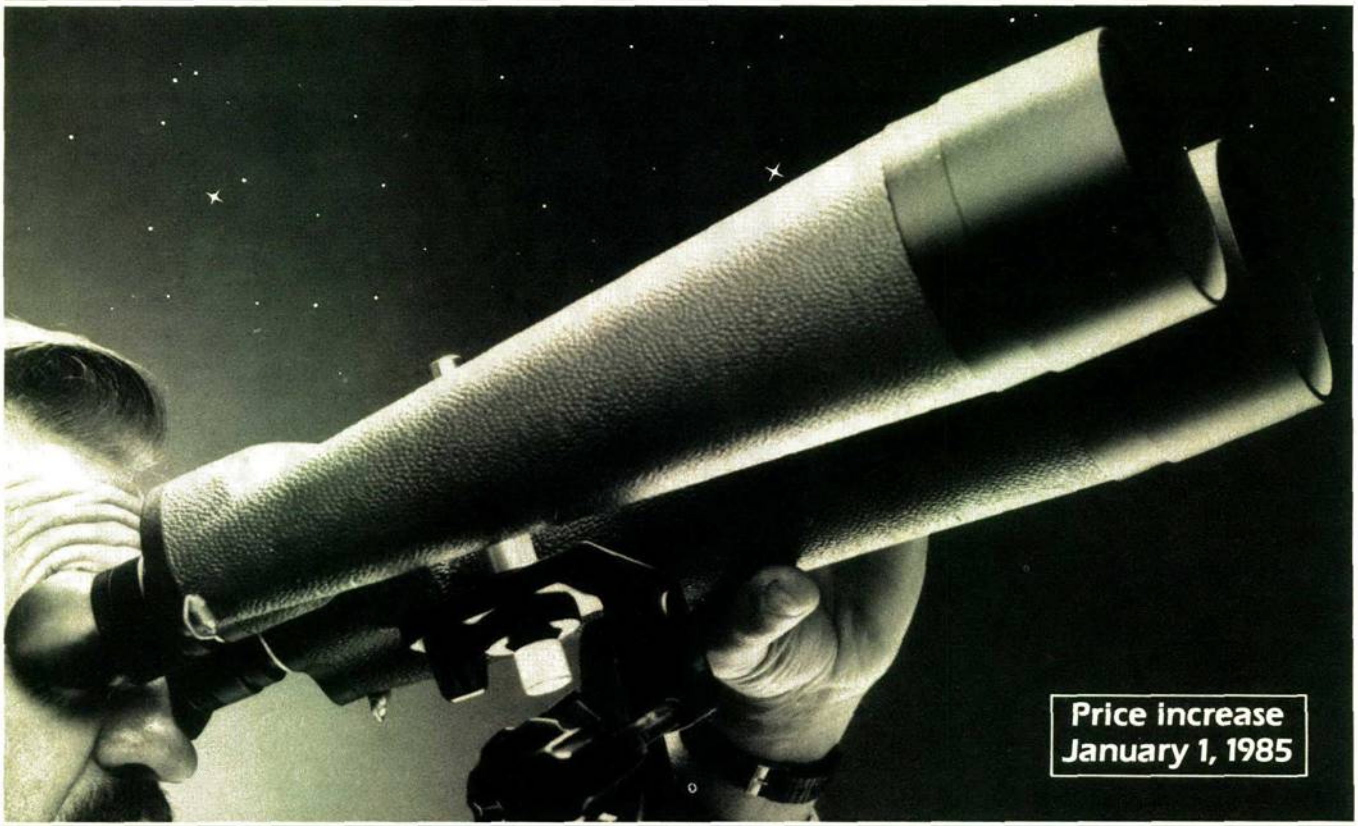

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Circumpolar Stars of the North

Gazer's Gazette

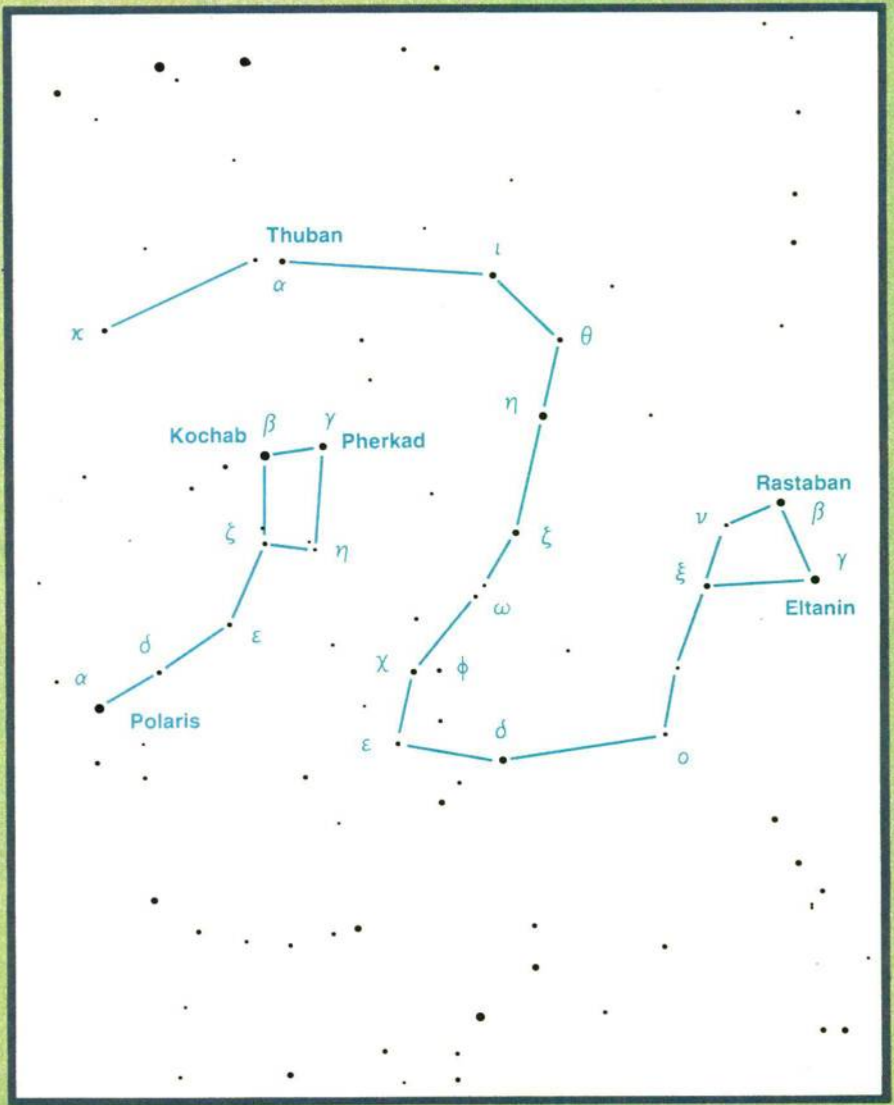
by
Earle F. Dodds

During the past year, we've looked at the seasonal constellations visible in the evening sky, concentrating on a wide swath of sky bordering the celestial equator. Now it's time to turn our attention to the northern circumpolar constellations — those which swing around the North Celestial Pole at high declinations and are visible, at one time or another, all year long.

One of the best known stars in the sky is Polaris, a fairly conspicuous white star which has been nicknamed the North Star because it lies less than a degree from the North Celestial Pole. In the northern hemisphere, Polaris is always above the horizon, is found at nearly the same spot in the sky, and therefore provides an accurate means for finding due north. Because of a gradual tilt change in the Earth's axis in space, Polaris will not always be the North Star; 4,600 years ago, Thuban — the brightest star in the constellation Draco — lay near the pole and was used for alignment by Egypt's pyramid builders. And 12,000 years ago, Vega — the brilliant bluish-white star which dominates the tiny constellation Lyra — held the position.

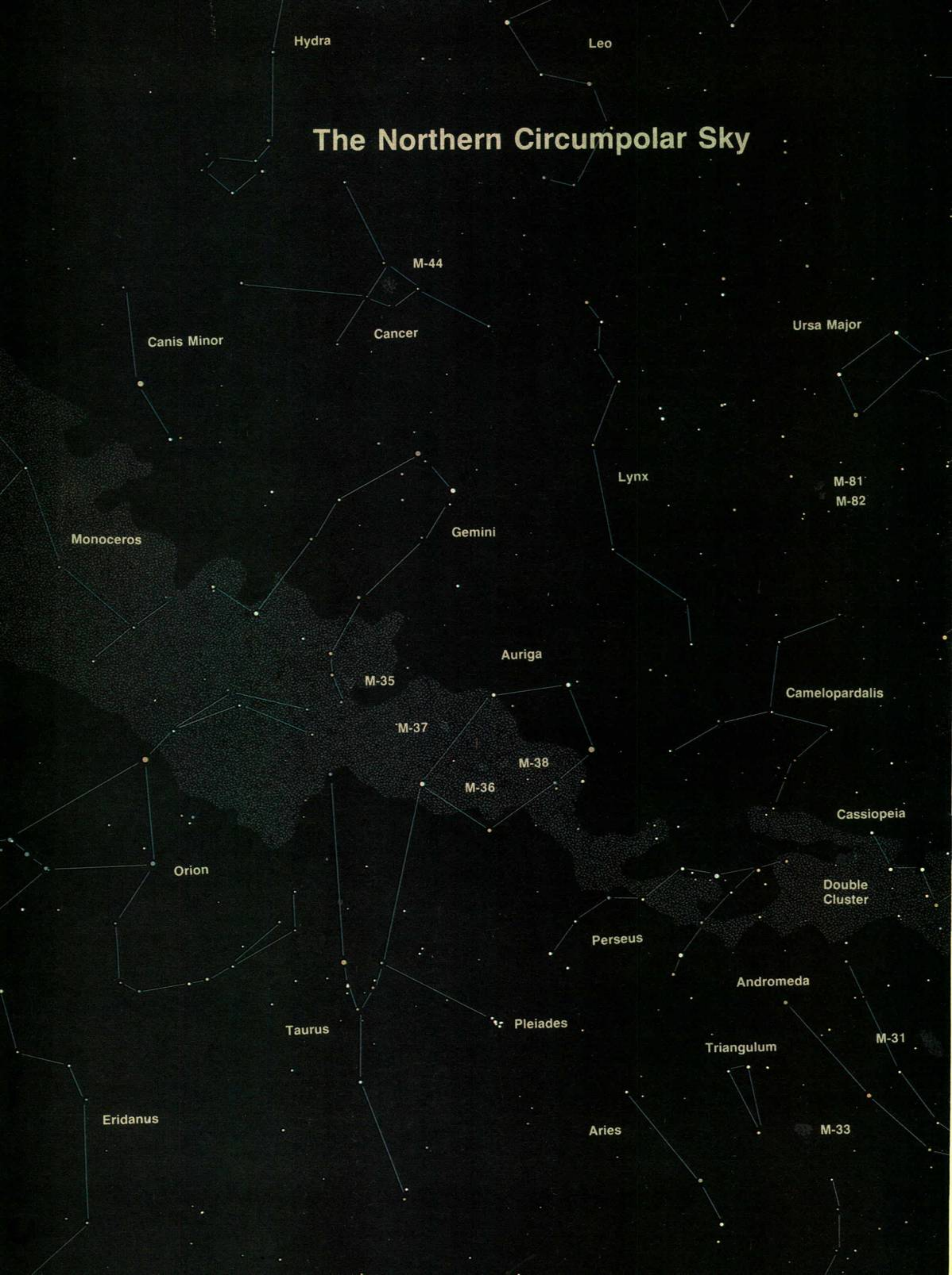
Polaris is also known as Alpha (α) Ursae Minoris, the brightest star in Ursa Minor, the Small Bear. At magnitude 2.0, Polaris is the 49th brightest star in the sky. It is slightly variable in light output, but not noticeably so with the naked eye. Polaris harbors a ninth-magnitude companion, which is a challenging test object for large binoculars because of the great difference in brightness between the two stars and close distance between them.

Ursa Minor is also known as the Little Dipper, an asterism of seven stars easily visible to unaided eyes under dark skies. Given slight haze or light pollution, however, the fainter stars in the Little Dipper fade out and make spotting it tricky. The two stars connecting Polaris with the bowl of the dipper are Yildun (Delta [δ] Ursae Minoris) and Epsilon (ε) Ursae Minoris. Both of these stars shine at fourth-magnitude, making them

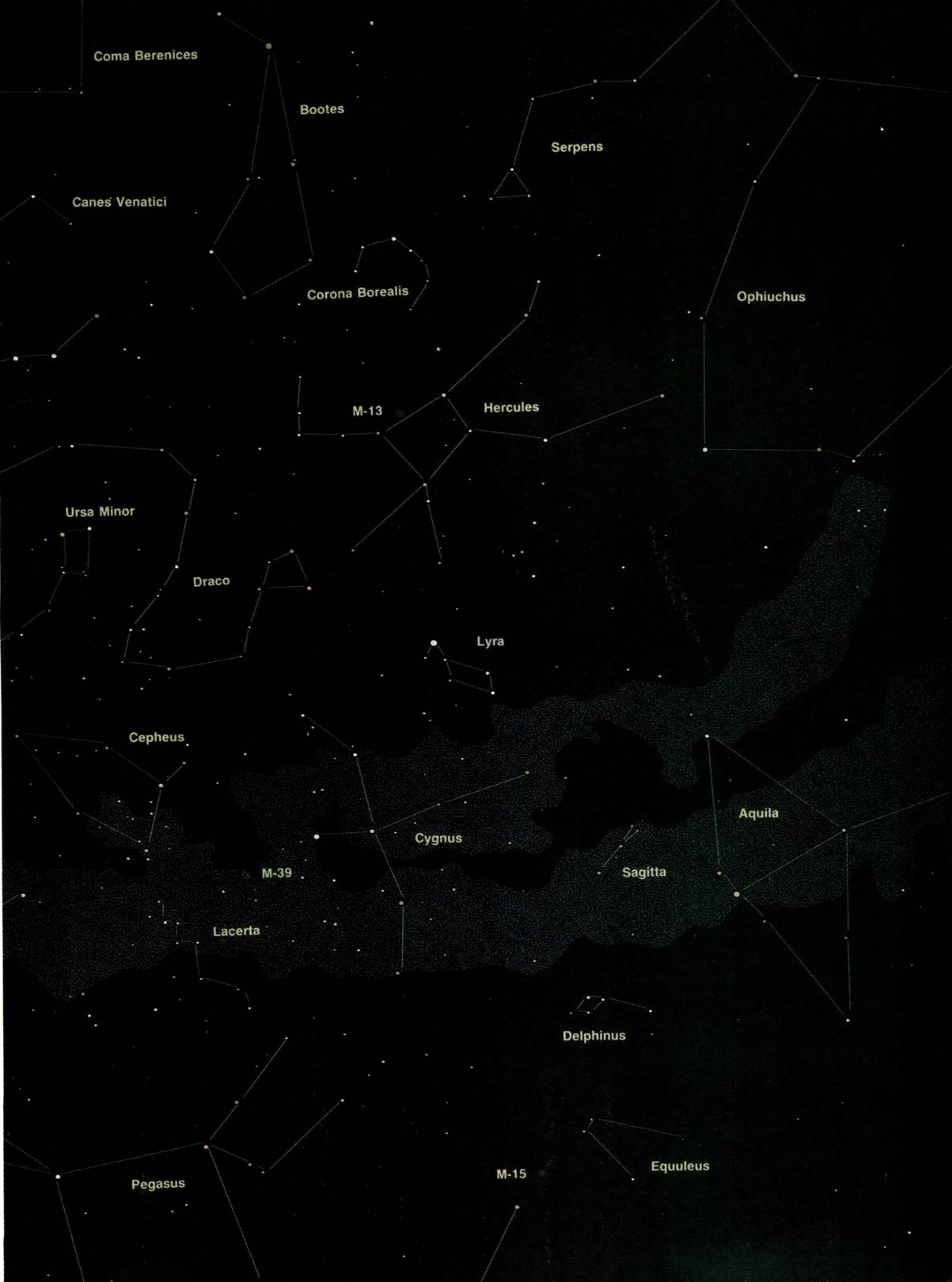


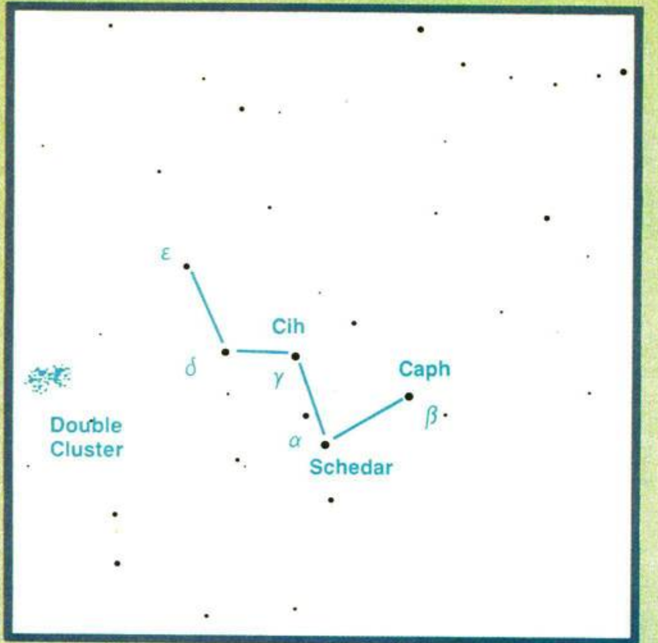
Well-known for containing the North Celestial Pole, the point around which stars appear to rotate, Ursa Minor is easily visible as a dipper-shaped group of third- and fourth-magnitude stars. Locating Polaris, the North Star, points the way to finding true north. Draco the Dragon twists around the dipper's bowl. Its brightest star is Thuban, which was the Pole Star 4,600 years ago.

The Northern Circumpolar Sky



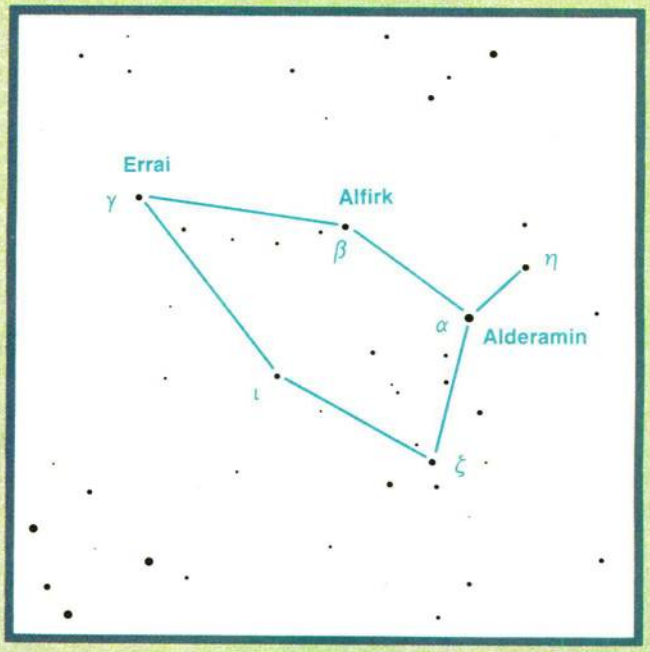
Hydra
Leo
M-44
Cancer
Canis Minor
Ursa Major
Lynx
M-81
M-82
Monoceros
Gemini
Auriga
M-35
Camelopardalis
M-37
M-38
M-36
Cassiopeia
Orion
Double Cluster
Perseus
Andromeda
Pleiades
Taurus
Triangulum
M-31
Eridanus
Aries
M-33


Coma Berenices
Bootes
Serpens
Canes Venatici
Corona Borealis
Ophiuchus
M-13
Hercules
Ursa Minor
Draco
Lyra
Cepheus
Aquila
Cygnus
M-39
Sagitta
Lacerta
Delphinus
Equuleus
M-15
Pegasus



Cassiopeia the Queen is bright and easily recognizable. Depending on time of night and year, Cassiopeia appears as an "M" or "W" formed by its five brightest stars. Nearby, the Double Cluster in Perseus looks like a faint doubled patch of fuzzy light.

Cepheus the King is a pentagon-shaped group of stars which doesn't stand out as well as Cassiopeia. Its brightest stars — Alderamin, Alfirk, and Errai — shine at second- and third-magnitude.



relatively inconspicuous. The bowl is composed of Kochab (Beta [β] Ursae Minoris), Pherkad (Gamma [γ] Ursae Minoris), Eta (η) Ursae Minoris, and Zeta (ζ) Ursae Minoris. Kochab is slightly fainter than Polaris, and is an orange-tinted giant star much closer to us in space than Polaris. Can you detect an orange color when looking at Kochab? Pherkad is a third magnitude bluish-white star, and Eta and Zeta — like the inconspicuous handle stars — glow at fourth-magnitude. The Little Dipper is highest during the evenings of early summer.

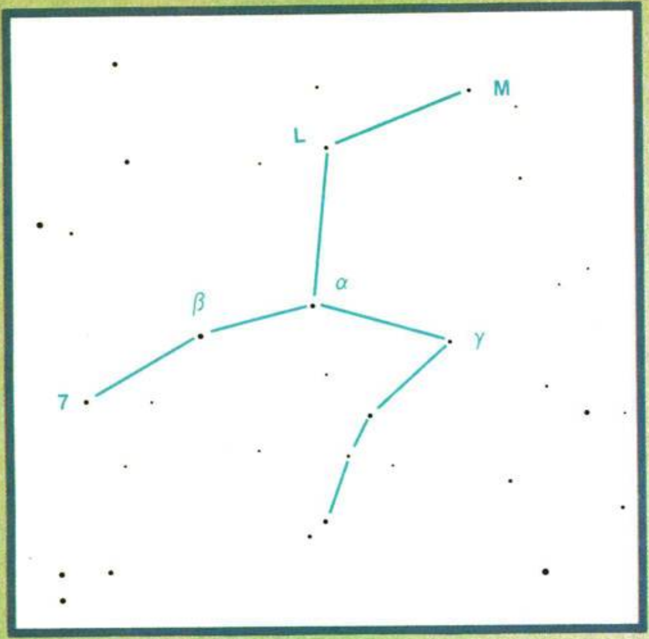
The sprawling constellation Draco the Dragon wraps itself around the dipper's bowl and consumes a large amount of the northern circumpolar sky. Draco's brightest star is Thuban (Alpha Draconis), which becomes a Pole Star every 26,000 years. It shines at magnitude 3.6 and is strongly bluish-white to the naked eye. Also found in Draco is a long string of stars which, together with Thuban, make up the dragon's contorted body. They are Kappa (κ), Iota (ι), Theta (θ), Eta, Zeta, Chi (χ), Tau (τ), Epsilon, and Delta Draconis; all third- and fourth-magnitude objects. Draco's figure is so large and contains so many stars that you may not recognize it without the aid of a star map — and even then it will take some time to locate all of its stars.

Easier to find is the dragon's quadrangle-shaped head, which includes Eltanin (Gamma Draconis), Rastaban (Beta), Grummium (Xi [ξ]), and Kuma (Nu [ν]). This distinctively-shaped group is an unmistakable feature of the sky, because it is isolated from other bright stars. Both Eltanin and Rastaban mean "dragon's head"; they shine at magnitudes 2.2 and 2.8, respectively. Eltanin shows a faint orange color, while Rastaban is a yellowish supergiant star of enormous intrinsic energy. It appears fainter than Eltanin because it lies nearly three times farther away from Earth.

Bright and unmistakable is the constellation Cassiopeia the Queen, perhaps the most prominent feature of the northern circumpolar sky. Cassiopeia is primarily composed of an "M" or "W"-shaped collection of five bright stars, representing the throne belonging to mythology's Queen of Aethiopia. From west to east, the stars are: Caph (Beta), Schedar (Alpha), Cih (Gamma), Delta Cassiopeiae, and Epsilon Cassiopeiae. Caph means "hand," which early Arabs thought Cassiopeia resembled. It is a yellowish-white star of magnitude 2.3, and lies close to Earth; the light you see from Caph left only 45 years ago. Schedar, which means "the breast," is the brightest star in the constellation — its pale yellow-orange colored light shines at magnitude 2.2. Cih, the centrally located star in Cassiopeia, is a bluish-white variable which hovers around magnitude 2.5. Delta and Epsilon are somewhat fainter, shining at magnitudes 2.7 and 3.4, respectively.

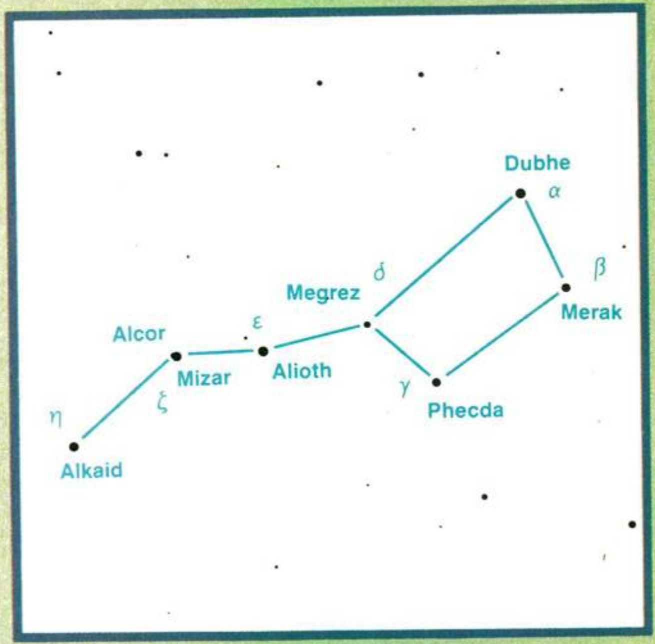
Since the stars in Cassiopeia lie toward a rich part of the Milky Way, binoculars will reveal innumerable faint stars cluttering the constellation. Near the southeastern end of the group, actually over the border into Perseus, you'll see a faint double patch of misty light. Binoculars will show this object as two grainy spots made up of faint stars. This is the Double Cluster of Perseus, comprising two of the finest examples of open star clusters in the sky.

Located between Cassiopeia and Draco is a fainter group of stars known as Cepheus the King. It's appropriate that Cassiopeia is next to Cepheus, because in mythology the Queen ruled Aethiopia along with her husband Cepheus. This constellation is not instantly recognizable, but its relatively faint stars show a distinctive pentagonal shape resembling a box-kite. The brightest star in Cepheus is Alderamin (Alpha Cephei), meaning "right-arm." It shines at magnitude 2.4 and gives off light that is pure white. Continuing northward along the pentagon, we find Alfirk (Beta Cephei), a bluish, slightly variable star which is normally at magnitude 3.2. Errai, also known as Gamma Cephei, is a yellowish-orange star equally as bright as Alfirk. The two remaining stars in the pentagon are Iota and Zeta Cephei, both fourth-magnitude stars without popular names.



One of the most overlooked constellations in the sky, Camelopardalis' brightest stars are fourth-magnitude objects. Alpha Camelopardalis is intrinsically bright, but appears dim because of its great distance.

The most familiar pattern of stars in the sky is the Big Dipper — the chief part of Ursa Major (the Great Bear). Dubhe and Merak, both second-magnitude stars, point the way toward Polaris and the North Celestial Pole. Mizar, the middle star in the dipper's handle, harbors close-by a fourth-magnitude companion which provides a test for keen eyesight.



Cepheus contains two unusual stars which are easily seen without a telescope. The first is Delta Cephei, the prototype of an important class of variable stars called Cepheids. The brightnesses of stars like Delta Cephei are so well known that astronomers can use them as distance indicators — even when they're found in other galaxies. Once you become familiar with Cepheus' form, try making a sketch showing the relative brightnesses of stars within the constellation. Keep doing this for a couple of weeks, and you'll notice that Delta regularly fluctuates in brightness over about a five-day period. At maximum it is a 3.5 magnitude star; at minimum it dims to magnitude 4.4.

The other unusual star in Cepheus is Mu (μ) Cephei, named the "Garnet Star" by the great English observer William Herschel. This is the reddest star visible to unaided eyes in the northern hemisphere — its color is striking, and noticeable even to first-time sky watchers. Mu is an irregular variable giant star, fluctuating between magnitudes 3.7 and 5.0, so don't be discouraged if it seems elusive once in a while. When it is at maximum brightness, Mu is unmistakably deep red. But as it dims, you'll note that funny things happen to the star's color. Does Mu seem consistently red to you?

A dim and often neglected circumpolar constellation is Camelopardalis the Giraffe. Its brightest star, Beta Camelopardalis, is a magnitude 4.2 yellowish supergiant star which is faint only by virtue of its great distance. The second brightest star, Alpha Camelopardalis, is a white star of magnitude 4.4. Bracketed by the brighter groups of stars Cassiopeia and Draco, Camelopardalis is rather insignificant to the naked eye.

Another circumpolar constellation is the most easily recognized pattern of stars in the sky — Ursa Major, the Great Bear, which contains the asterism called the Big Dipper. Ursa Major is principally composed of seven bright stars forming the dipper shape, although it covers much more sky with two long appendages of slightly fainter stars. The stars forming the dipper's handle are Alkaid (Eta), Mizar (Zeta), and Alioth (Epsilon Ursae Majoris), all of which are second-magnitude objects. Alkaid, the "end of the tail," is a 1.9 magnitude bluish-white star. Alioth is a pure white star at magnitude 1.8. Mizar, the "girdle," shines at magnitude 2.0 and harbors a little fourth-magnitude companion to its northeast, found about half a Moon's diameter away. Throughout history, sighting the companion — named Alcor — has been used as a test for sharp eyesight. Can you see this fainter star hovering just off of Mizar?

The Big Dipper's bowl contains four bright stars, two of which are known as the "pointer stars" because they mark the path toward Polaris. These are Dubhe (Alpha) and Merak (Beta Ursae Majoris), which shine at magnitudes 1.8 and 2.3, respectively. Dubhe — meaning "the bear" — is a yellowish-orange star (although its color is somewhat difficult to perceive), while Merak — which means "loins of the bear" — is a bluish-white star. On the other side of the bowl are Phecda (Gamma) and Megrez (Delta Ursae Majoris), which are slightly fainter stars. Phecda, meaning "thigh," is a magnitude 2.4 star with a strong white tinge. Megrez, "root of the tail," shines at magnitude 3.3 and is a bluish-white object.

Found north of the dipper's bowl are two faint galaxies which show up well in binoculars as tiny fuzzy ovals. These are M-81 and M-82, a spiral and an irregular galaxy, located 6.5 million light-years away. Though they may not be impressive objects under less-than-perfect skies, contemplating their great distances and realizing that their light comes from millions of individual stars is an unforgettable experience on a cold December night.

Providing you observe for several hours, you can see a great variety of circumpolar constellations circle around Polaris and the North Celestial Pole. Viewing them carefully — their star patterns, brightnesses, and colors — will introduce you to a good mixture of the sky's most renowned and familiar sights, and give you valuable experience as a backyard sky observer.

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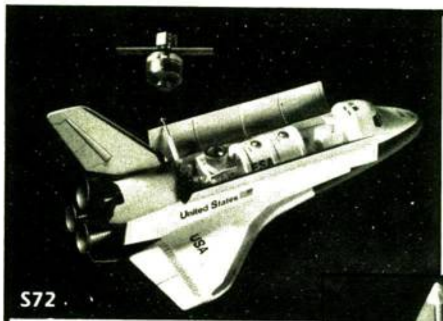

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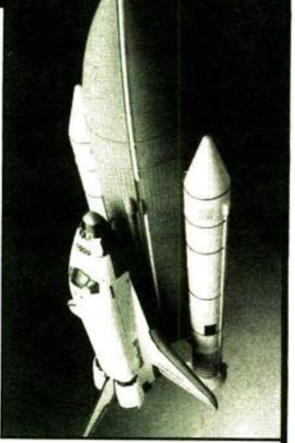

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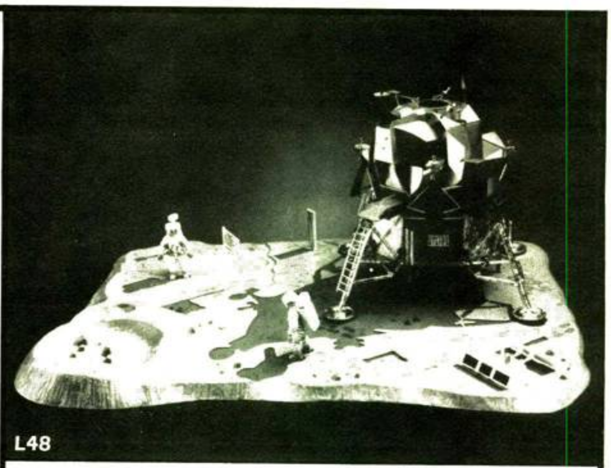

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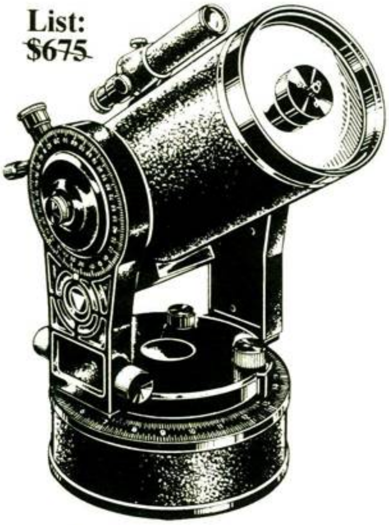

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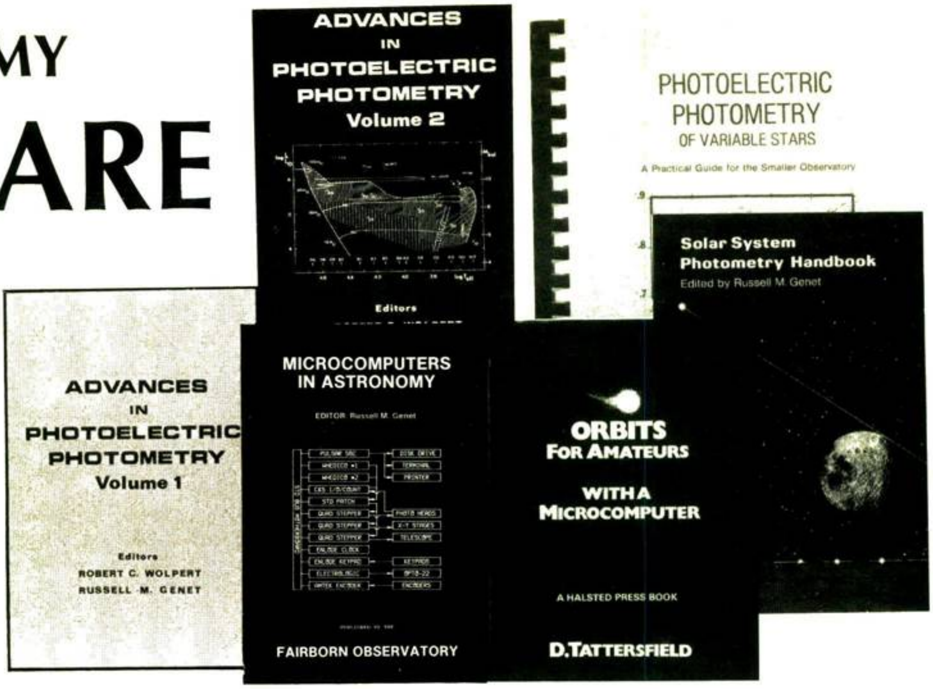
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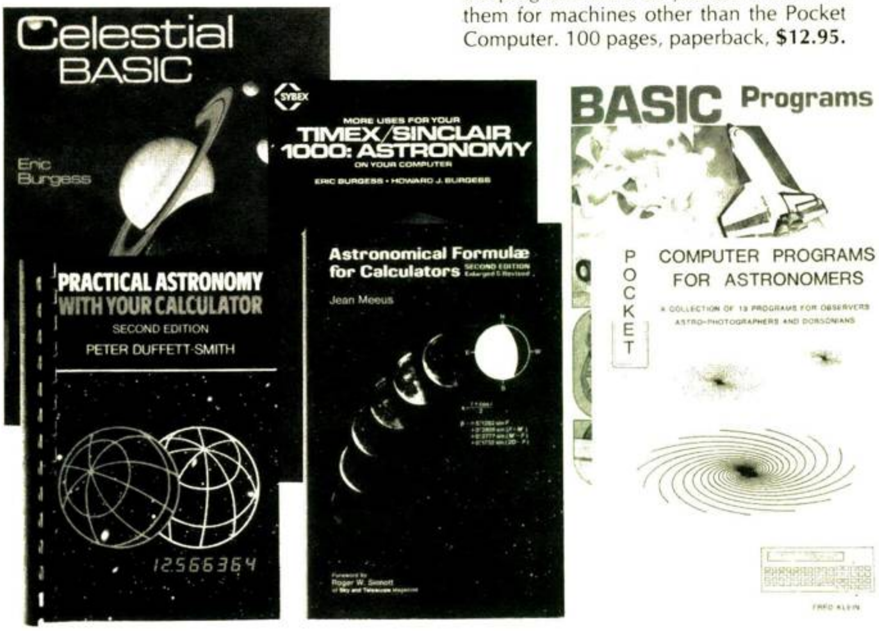
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ASTRO NEWS

New Optical Pulsar

A new pulsar, discovered in March 1984 through observations with the Einstein X-ray satellite, has now been observed at optical wavelengths also. This is the third optical pulsar known, along with those in the Crab Nebula in Taurus and the Vela supernova remnant. The new optical pulsar is about 150,000 light-years from Earth and is located in the Large Magellanic Cloud.

The pulsar flashes once every 50.28149 milliseconds, or about 20 times a second, and appears to be slowing at a rate of about 1/20,000 second per day.

Dr. Carl Pennypacker of the Lawrence Berkeley Laboratory and the Space Science Laboratory at the University of California says this discovery will enable scientists to better understand how pulsars fit into the overall cycle of stellar life and death. Before this discovery, only the Crab pulsar was bright enough at optical wavelengths to be observed in detail.

The new pulsar was discovered by astronomers Frederick Seward and Frank Harnden Jr. of the Harvard-Smithsonian Center for Astrophysics, and David Helfand of Columbia University. Optical photographs of the pulsar were taken last August by Pennypacker and John Middleditch, of the Los Alamos National Laboratory in New Mexico, using the 4-meter telescope at the Cerro Tololo Interamerican Observatory in Chile. *Tom Kovach*

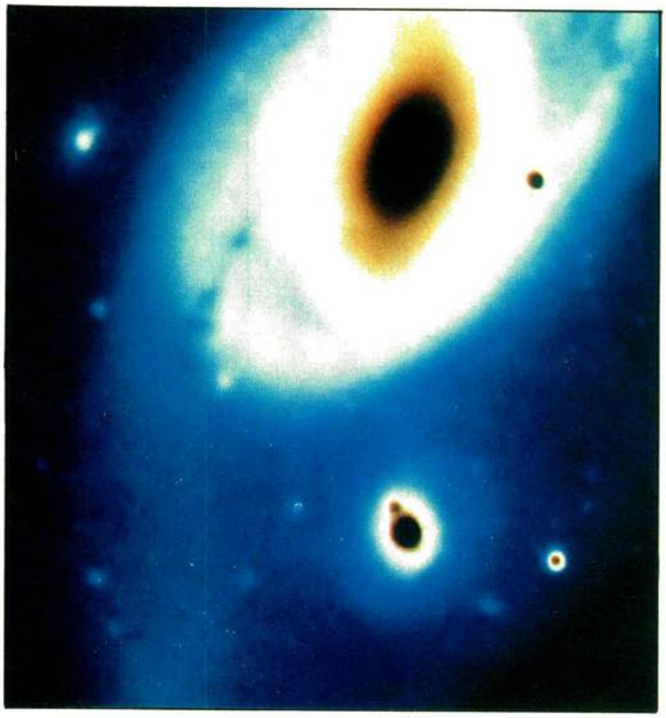

Photo courtesy Gerald Cecil

What is interacting with what? This composite image shows the spiral galaxy NGC-4319, the quasar Mrk 205, and the compact galaxy with which the quasar may *really* be interacting. See story for details.

NGC-4319 and Markarian 205: The Final Picture?

Ever since the discovery of quasars in the late 1950s, astronomers have been divided into two camps: one group believes that the objects are extremely distant — "at the edge of the observable universe" — while the other group holds that quasars are relatively nearby constituents of the cosmos. Although quasar redshifts imply great distance, the prodigious amount of energy these objects seem to emit makes their redshift-derived distances difficult for many astronomers to believe.

In the history of this "quasar debate," two objects have received considerable attention from both sides: the spiral galaxy NGC-4319 and the quasar Markarian 205. In fact, the pair have been called "the fulcrum of the entire redshift controversy." The redshift of NGC-4319's spectrum suggests that it lies at one-tenth the distance of the quasar, yet the quasar appears to be connected to the outer fringes of the galaxy's arms. For more than a decade, astronomers in both camps have tried to determine the reality of the apparent "bridge" between Mrk 205 and NGC-4319.

Those who believe quasars to be close argue that the apparent connection between these objects is real, and that it constitutes evidence of interaction between a galaxy and a quasar at very different redshift-derived distances. They add that if redshift is not a reliable indicator of quasar distance, then many quasars could indeed be nearby objects. Astronomers who take the traditional stand on quasar distances have reached either of three conclusions: 1) the connection between the objects does not exist; 2) the connection exists but is a photographic artifact, not a real object; 3) the connection we see is actually faint background galaxies lying between the two objects. (See "Are Quasars Far Away?" in the October 1984 issue.)

University of Hawaii astronomers Gerard Cecil and Alan Stockton made the most recent attempt to settle this argument and came to a surprising conclusion. Using a charge-coupled device (CCD), the astronomers made deep exposures of the galaxy/quasar pair. Their findings, to be published in the January 1, 1985 issue of *The Astrophysical Journal*, confirm the existence of the luminous feature. They argue that it is "neither an artifact of the overlapping smooth luminosity distribution of NGC-4319 and Mrk 205 nor a chance superposition of a background source unrelated to either object." Instead, the astronomers found evidence that Mrk 205 is interacting with a compact companion galaxy just three arc-seconds to the north-northeast — and which is at the same distance. "We are indeed dealing with a remarkable juxtaposition: a chance superposition of a foreground spiral and an unrelated active galaxy undergoing interaction with its own companion, all *three* objects being at distances consistent with their own redshifts."

The NNTT? It's An MMT!

A scientific advisory committee authorized by the National Optical Astronomy Observatories to choose between competing designs for a National New Technology Telescope (NNTT) has made its recommendation. The giant 15-meter instrument will use a multiple-mirror optical system.

The recommendation resolves a dilemma in choosing between one of two technically balanced but very different concepts. One would use a segmented mirror composed of many smaller carefully fitted mirrors. This would be mounted and controlled to function as a single 15-meter mirror, a design now being applied to the 10-meter telescope proposed by the University of California.

The multiple-mirror concept uses four 7.5-meter mirrors which are actually four individual 7.5-meter telescopes. When operating together, these provide the resolution equivalent to a single 15-meter mirror. The Multiple Mirror Telescope, a smaller version of this system, now operates at the Smithsonian Institution/University of Arizona facility on Mount Hopkins. In a sense, the design selected for the New Technology Telescope will use the Mount Hopkins system as a smaller prototype.

According to Robert Gehrz, the University of Wyoming astronomer who chairs the scientific advisory committee, the multiple-mirror concept was chosen because of its marginally superior performance in certain key applications. "Some of the most important science to be done with the world's largest telescope will require high spectral and spatial resolution, and the multiple-mirror concept seemed, on balance, to offer outstanding and versatile performance in those applications." The committee also notes that both concepts represent desirable new directions in optical astronomy and that development of the segmented-mirror technology at California is "healthy."

"This represents a first step for us," notes John Jeffries, director of NOAO. "Now we shall begin to define the project, and to initiate the detailed engineering study of all aspects of the total system — the building, site, mounting, optics, management, instrumentation — all those things. This will culminate in a proposal in about two years' time, with an eye toward construction funding in fiscal year 1987."

Exosat: Preliminary Findings

The European X-Ray Observational Satellite (Exosat) project began in the late 1960s, when scientists started planning a mission to determine accurately the positions of intense X-ray emissions. By the mid-1970s, several X-ray astronomy missions had been flown,

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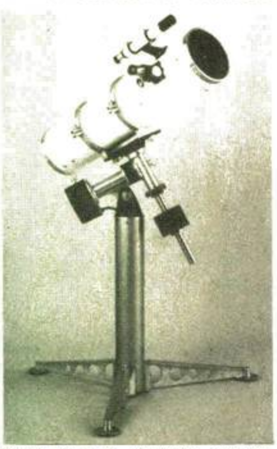

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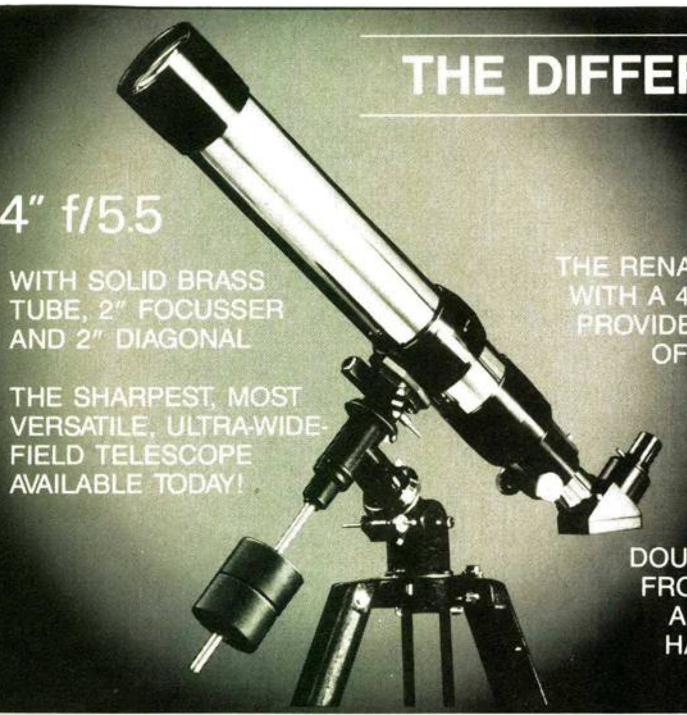

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commencing with Uhuru and progressing quickly through a sequence of spacecraft — Ariel V, ANS, OSO-8, SAS-3, the Einstein Observatory, and finally Ariel VI. These flights concentrated on detecting and identifying X-ray sources at low energies and monitoring the behavior of these mysterious, extremely active sources.

In 1973, Exosat was finally approved, but unforseen financial difficulties shelved the spacecraft until 1977. Finally, 10 years after approval and 5 years after development commenced in earnest, Exosat was launched atop a Delta-3914 from the Vandenberg Test Range in May 1983. In June, Exosat began transmitting a mass of illuminating, often surprising data.

Cosmic X-ray astronomy focuses on some of the most active and highly energetic phenomena in the universe. The physical processes that lead to the bulk of the radiation being transmitted at X-ray wavelengths are often thermal in origin, involving hot gases at temperatures ranging from millions to hundreds of millions of degrees. Many of the sky's most intense sources of X-ray radiation are in our own Galaxy, so Exosat's initial observations concentrated on galactic sources. These range from nearby normal stars, like our own Sun, to white dwarfs and even more unusual objects like compact neutron stars and possible black holes.

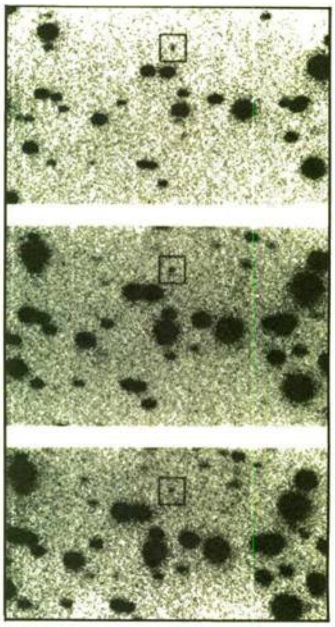
Observations made in the 2 to 30 keV energy bandwidth, performed by the medium-energy experiment and the gas scintillation proportional counter, have provided data on the overall temperature of supernova remnants and the presence of heavy elements like iron. The data have provided astronomers with fuller information on the fluctuations in gas temperatures and mass throughout the remnants. Detailed high-resolution images in a number of broad wavebands will lead to a better understanding of the interaction between a supernova blast wave and the surrounding interstellar medium.

Not long after Exosat's first data transmission, it became apparent that astronomers had overestimated the radiation of the celestial background. As a result, the medium-energy experiment and gas scintillation spectrometer, which examine the background environment, had been calibrated to reject a large amount of background "noise" when scanning for a point source of X-rays. In fact, the actual level of background radiation was far lower than expected — a welcome surprise for astronomers, who can now search for even fainter X-ray sources.

Most of these faint sources are extragalactic in origin, which means that Exosat should detect many hundreds of additional sources, particularly via the medium-energy experiment in the 2 to 20 keV energy range. Indeed, Exosat's low-energy telescopes have already been trained on our sister galaxy M-31 in Andromeda. They have found many individual sources that are probably associated with the same types of objects as those producing X-rays in our own Galaxy — supernova remnants and close binary stars, for example. Detailed analysis of the data will take some time, but preliminary results reveal a multitude of new sources.

While Exosat was still being tested in preparation for full-time scanning, a white-light flare occurred in the old nova system GK Persei, which originally erupted in 1901. Such optical outbursts occur very rarely, but on this occasion Exosat was on standby. Its observing schedule was altered to take advantage of this unusual event, and the spacecraft made an eight-hour exposure of this binary system. Exosat quickly detected a 351-second periodicity in the star's X-ray flux. The pulsations result from the motion of a white dwarf about a normal stellar companion, indicating that the dwarf has a strong magnetic field that channels hot, X-ray emitting gas from the companion (often a red giant) down onto its magnetic poles. The X-ray source appeared brighter than expected, revealing a definite correlation between X-ray energy levels and the optical flare-up. When combined with data from additional scans and high-resolution optical measurements, Exosat's observations will provide further details on the dynamics of this curious binary system and the physics of the gas accretion process.

A consequence of Exosat's highly eccentric deep-space orbit is its practically continuous contact with the Observatory Operations Centre in Darmstadt, West Germany. This center will also be used for the Giotto (Comet Halley encounter) mission in 1986. Coupled with real-time data-processing capable of handling data ranging from mere microseconds to scans lasting 80 hours, Exosat's constant contact has enabled the science team to react to unexpected results virtually in parallel with the spacecraft's operations. Observations of the cataclysmic binary system AM Herculis, which has a binary orbital period of three hours, illustrates this. Observations made by X-ray satellites in near-Earth orbit, with periods of around 1.5 hours, are severely hampered in their ability to observe such unpredictable and variable sources. Exosat's orbital path ranges from 500 to 200,000 km, and it studied AM Herculis for more than six binary cycles. Exosat found that the binary's X-ray emission flickered, and it determined when the source eclipsed its companion star.



These photos, made with the 5-meter Hale telescope at Palomar Observatory and taken about 20 minutes apart, show Comet Halley (in box) on January 7, 1984. The top photo was made in green light, the middle in red light, and the bottom in infrared light. Taking them through different color filters enabled G. Edward Danielson of Caltech and David Jewett of MIT to study the comet's color, which they found to be very reddish. When the exposures were made, Halley was about 800 million miles from the Sun and 700 million miles from Earth; its starlike appearance suggests that it had not yet formed a gaseous coma.

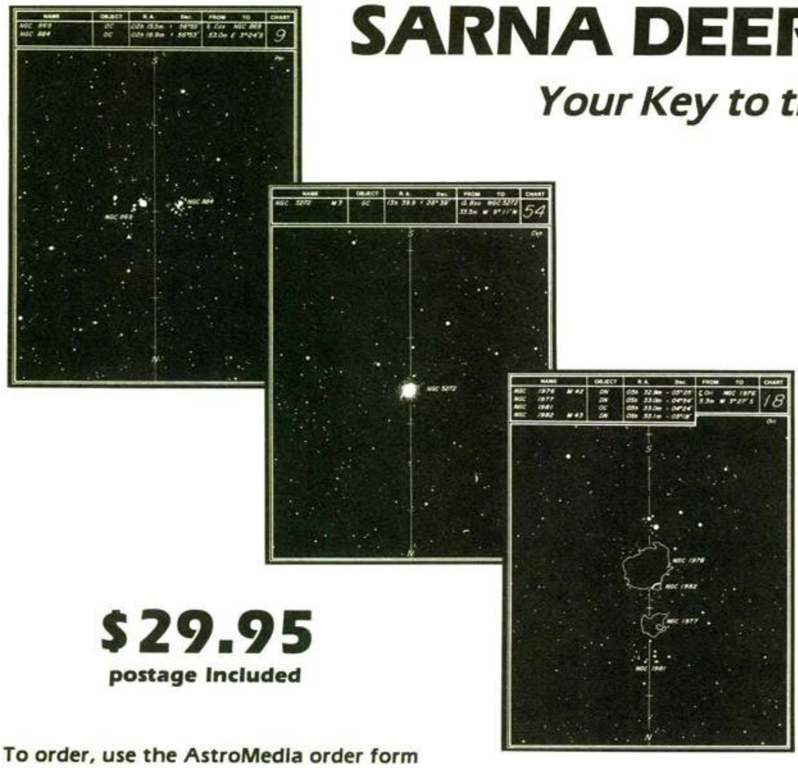
While in the process of carrying out routine observations, Darmstadt was notified by Japanese X-ray astronomers of the sudden and dramatic appearance of an X-ray star half as bright as the brightest such source in the sky — a so-called X-ray transient. The simple instrumentation aboard the small Japanese satellite Tenma was not sensitive enough to locate the star more than generally, so Exosat was immediately maneuvered to point to that region. Some hours later, analysis of the telescope data revealed the source's location to within approximately 15 seconds of arc. Optical observatories around the globe were notified so that they could attempt to identify the source's optical counterpart. Danish optical astronomers have already found evidence for an erratic star at the location of the X-ray sources. A detailed analysis of the data for the whole payload should, when coupled with the optical data, provide information on the nature of the object.

Exosat is now well into its main observational period and has already scanned X-ray emissions from Jupiter, normal stars (like Algol), white dwarfs (Feige 31) and a wide selection of extragalactic objects, including active galaxies and quasars. Exosat will be open to international science groups with observing time split half-and-half between the hardware groups and guest astronomers. It is expected that over 75 percent of the observing time will be given to visiting teams. This will make Exosat an observatory facility accessible to the entire scientific community, very similar to a ground-based optical or radio telescope. *Aldo Rabaiotti.*

Comet Giacobini-Zinner Recovered

A team of astronomers at Kitt Peak National Observatory have pinpointed the position of Comet Giacobini-Zinner — target of the first space mission to a comet. Early discovery of the comet was critically important to the mission of the International Cometary Explorer, a U.S. spacecraft scheduled to pass through the comet's tail on September 11, 1985.

Working with the latest electronic detectors and the 158-inch Mayall Telescope, Stanislaus Djorgovski and Hyron Spinrad of the University of California at Berkeley and Kitt Peak astronomers George Will and Michael Belton found the comet just four seconds of arc from the predicted position. This amounts to a 6,000 mile difference in the comet's location, so the orbit of NASA's spacecraft currently en route to the comet may require just a small correction.



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ASTRO NEWS

Giacobini-Zinner is a small, active comet that displays a well-developed tail of charged particles when it is close to the Sun. The comet was discovered in 1900 and has been observed at 10 returns since then. Its motion is known to be erratic because of forces exerted by material vaporizing from the nucleus, which acts in a manner similar to a rocket exhaust. Because of this erratic motion and the need to target the International Cometary Explorer precisely, astronomers made special efforts to sight Giacobini-Zinner at the earliest possible time.

When launched by NASA in August 1978, the spacecraft was originally named the International Sun-Earth Explorer 3 (ISEE-3). It is part of a three-spacecraft effort to study the response of the Earth's magnetosphere to the stream of particles emitted by the Sun. Since the U.S. would not fund a new mission to Halley's Comet in 1986, NASA decided to use the half-ton ISEE-3 instead. In the most complex series of maneuvers ever undertaken by any NASA craft, ISEE-3 made multiple passages around the Moon in order to hurl itself out of Earth's orbit and toward Giacobini-Zinner. The comet will be about 44 million miles from Earth when the International Cometary Explorer passes through its tail.

Rapid Rotation in the Pleiades

The Pleiades is one of the most beautiful star clusters in the sky and is easily visible to the naked eye. Lying just 430 light-years away, it is also one of the nearest. Because the Pleiades is fairly young (about 70 million years), astronomers often study it to investigate the early stages of stellar evolution.

Now a team of astronomers at the Harvard-Smithsonian Center for Astrophysics has found that many late-type (cool) stars in the Pleiades rotate rapidly — a discovery that has important implications not only for early stellar evolution but also for the determination of cluster ages. John Stauffer, Lee Hartmann, David Soderblom, and Neal Burnham report their discovery in the May 1, 1984 issue of the *Astrophysical Journal*.

Rapid rotation broadens the spectral lines of a star: one limb of the spinning star approaches us and produces a blueshift, while the other recedes from us and produces a redshift. The net effect is a broader spectral line. Looking at this "Doppler broadening," the scientists measured the rotation rates of 65 stars in the Pleiades: 11 were of spectral type G, 38 were of type K, and 16 were of type M.

Most stars proved to be slow rotators, but 18 are rotating rapidly — with projected equatorial velocities between 25 and 140 km/sec. This result is very surprising: although many B, A, and F-type stars in the Pleiades and elsewhere rotate rapidly, nearly all late-type (G, K, and M) main sequence stars rotate slowly. Stranger still is the discovery that all of these late-type rapid rotators are either K or M-type stars; all the G stars rotate slowly. And to complicate things further, there are also plenty of other K and M stars in the Pleiades that rotate slowly.

Why is rapid rotation among late-type stars in the Pleiades confined to spectral classes K and M? And why are K and M stars elsewhere content to rotate slowly? The scientists propose this model: as the core of a young star contracts prior to reaching the main sequence, it spins up — just as an ice skater spins faster by drawing in his arms. A typical K star has a mass of 0.75 suns and its core takes about 70 million years to contract. It then takes another 30 million years to settle onto the main sequence. Since the Pleiades is about 70 million years old, K-type members have just contracted their cores and are spinning fast as a result.

G-type stars are more massive and evolve faster. The core of a star with the mass of our Sun takes only 25 million years to contract. Presumably the contraction spun up the G stars in the Pleiades too, but they have had more than 40 million years to spin down from the initial spin-up. So all the G stars now rotate slowly.

The scientists believe that stars may be born with a large spread in spin rates. A very slow-spinning star may speed up when it contracts, but it still won't be spinning very fast. This may be why there are other K and M stars that are slow rotators: these stars were simply born as slow spinners.

If this idea is right, other young star clusters should show the same feature, and this would allow a check on some cluster ages. Astronomers traditionally determine the age of a cluster by looking at the turn-off point — the break in the main sequence where stars start evolving into red giants. In the Pleiades, this break occurs at spectral type B; the fact that some of these short-lived B stars are still on the main sequence is how we know the Pleiades is about 70 million years old. Now, however, astronomers may be able to look at the turn-*on* point — where late-type main sequence stars start spinning fast. The cluster's age is then the time it takes a star of that spectral type to contract its core. The later the turn-on point, the older the cluster.

The scientists plan to study other clusters to check their theory, but there are already indications that it is right. For one thing, all late-type stars studied in the older Hyades cluster (about 600 million years old) spin slowly. The Alpha Persei association, on the other hand, is younger than the Pleiades; its age is about 50 million years. Preliminary results, not yet published, indicate that this group, unlike the Pleiades, does contain some rapidly rotating G stars.

This discovery was not a complete surprise. Rapid rotation in a late-type star induces strong magnetic fields, which in turn cause starspots. As the starspots rotate in and out of view, the star's light varies periodically. In 1981 Floor van Leeuwen of the Royal Greenwich Observatory and Peter Alphenaar of Leiden Observatory discovered just such variability in the light from some of the Pleiades K stars — the first hint that these stars were rotating rapidly. *Ken Croswell.*

Hawaiian Observing Site

The Mauna Kea, Hawaii, Astronomical Society, in conjunction with the University of Hawaii, has opened up an observing site for amateur astronomers on Mauna Kea, which houses some of the world's largest and most active professional telescopes and offers exceptional seeing and transparency. The amateur observing site is located at 9,000 feet at Hale Pohaku, on the road that leads to the observatory. Situated at 14,000 feet on the summit, the Mauna Kea Observatory itself offers guided tours on weekends from May through September, including viewing through a 24-inch telescope. A four-wheel drive vehicle is required to reach the summit; jeeps are available for rent in nearby Hilo or Kona.

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February 15-17
First Annual Winter Star Party, Everglades National Park, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Richard Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

April 18-21
National Convention of the National Science Teachers Association, Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington, DC 20009.

June 28-July 1
Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, 412 Hermitage Rd., Edmonton, Alberta, Canada T5A 3K9.

July 15-24
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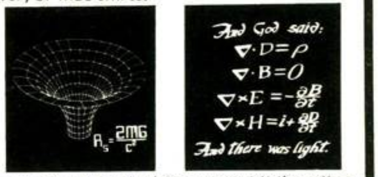

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Tuning in to the Interior of a Star

by Dermott J. Mullan

In their study of the stars, astronomers usually find themselves severely restricted — they can only examine radiation from the material near a star's surface. Of course, the word "surface" suggests an entirely inaccurate picture of a star, for there is nothing solid about any particular stellar layer. What astronomers refer to as a star's surface is actually a layer of gas so dense that radiation (light, radio waves, X-rays, etc.) can penetrate no further. Regions below that level are essentially invisible to a detector sensitive to the radiation in question. For visible light, this surface is called the *photosphere*. Gas beneath the photosphere of the Sun becomes opaque so rapidly that we can see nothing below about a hundred kilometers. This region available for study is very small compared with the 700,000 kilometer radius of the Sun — solar observations essentially go only skin deep. Optical "security" is so tight that most of the Sun is beyond our observational grasp.

Fortunately, the Sun gives off more than just visible light. Although radiation of other wavelengths also encounters a barrier, the depth of this opaque level is usually different from that for visible light. For example, infrared radiation at wavelengths about three times longer than that of visible light allows us to see somewhat deeper layers of gas. On the other hand, radio waves in the microwave and meter-wave part of the spectrum can escape only from regions high in the solar atmosphere, up to hundreds of thousands of kilometers above the surface. At the other end of the electromagnetic spectrum, X-rays emitted by million-degree gas can escape the outer atmosphere of the Sun almost down to the photosphere. The material inside the Sun is also hot enough to emit X-rays, but this radiation is inaccessible to detectors trying to peer in from the outside. The overlying gas, with its churning ions, electrons, and neutral atoms, will not allow the passage of X-rays, so we cannot detect radiation from the most interesting part of the Sun — its interior.

How, then, can we know *anything* about what is happening deep inside the Sun and stars?

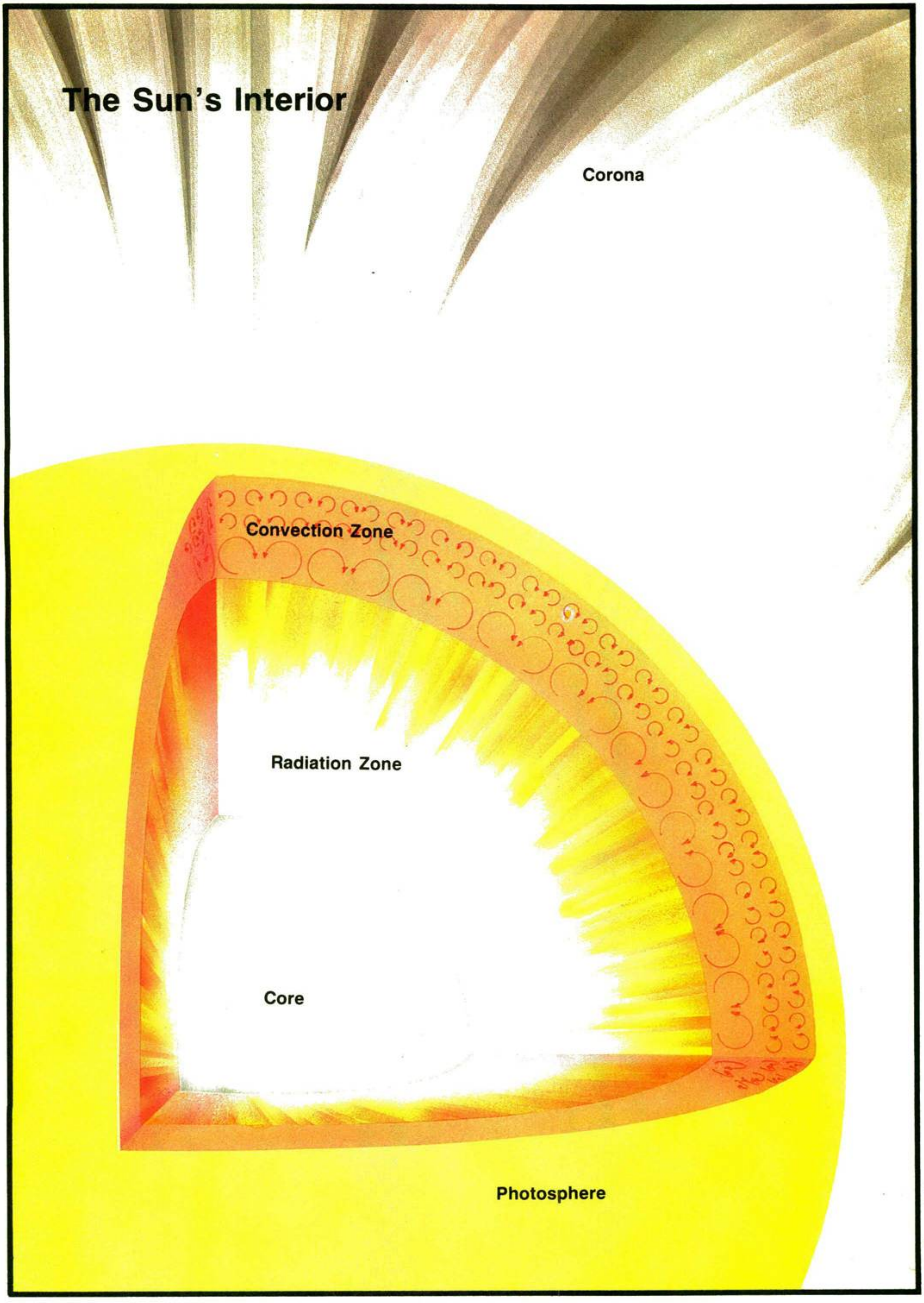
For many years, the only available information came from theoreticians, who derived equations to describe the behavior of gas inside a star. For example, physicists know that heat moves from place to place by three processes: conduction, convection, and radiation. When theoreticians applied the mathematical formulations of these processes to conditions within stars, radiation and convection emerged as the dominant modes of energy transfer. Nuclear reactions at the very hottest parts of a star (near the center) release energy that is transported to the stellar surface, where it journeys across space to our detectors. In stars like our Sun, theory suggests that this energy moves mainly by radiation in the dense inner regions, and mainly by convection near the surface.

These results have become part of a standard view of the solar interior. According to this picture, the Sun's gas is convective from the surface down to a depth of about one-quarter or one-third of its radius, and radiation dominates the region from the base of the convection zone all the way down to the Sun's energy-producing core. By studying the Sun in visible light, we can view the topmost layer of convecting material: it looks like bright, hot bubbles of gas surrounded by darker, cooler material. Hot gas rises from lower regions, darkens at the surface as it loses energy and cools off, then sinks back down into the Sun. The key aspect of the convection zone beneath the surface of the Sun (and presumably other similar stars) is that the gas moves at significant speeds in essentially all directions. The end result, of course, is that heat moves upward to the surface. But at any particular region within the convection zone, the gas does not simply flow upward. In fact, the gas flow at all depths is very turbulent — small eddies break off from larger eddies, and these in turn spawn their own turbulent wakes as they plow through neighboring gas.

In the standard picture of a stellar interior, astronomers view the convection zone as a channel for carrying the thermal energy that will eventually emerge from the surface of the star as heat and light. Astronomers have paid less attention to another important property of the convection zone, namely the energy associated with the rapid motions of the turbulent eddies themselves. This type of energy, referred to as mechanical energy, involves mechanical work as gas pushes its way to the surface. Convection necessarily produces mechanical energy as it transports heat.

This seems trivial because it sounds so obvious, but the existence of mechanical energy opens up an entirely new "window" for astronomers. The ions and electrons which create a barrier for light and X-rays do not hinder mechanical energy. If a suitable channel exists, mechanical energy can pass from deep in a star's interior to its surface with little difficulty. By examining the Sun's mechanical energy output, we can see through its outer layers almost as if they were transparent and peer deep into the convection zone. But before examining this in detail, let's discuss two other recent techniques used to look into the Sun.

Astronomers first began using a detector that responds to something emerging from deep within the Sun about 15 years ago, when the solar neutrino experiment came "on line." Neutrinos, energetic particles produced in nuclear reactions near the center of the Sun, do not easily interact with other matter. These tiny particles speed out of the Sun's core and pass through its outer regions without hindrance. An Earth-based detector tuned to the appropriate energies can record solar neutrinos as they pass through it. This experiment, which has been running continuously since 1968, has found only one-fourth to one-third the number of neutrinos originally predicted by astrophysicists. This indicates that some of our ideas about the Sun's interior might not be as accurate as we originally thought. Additional

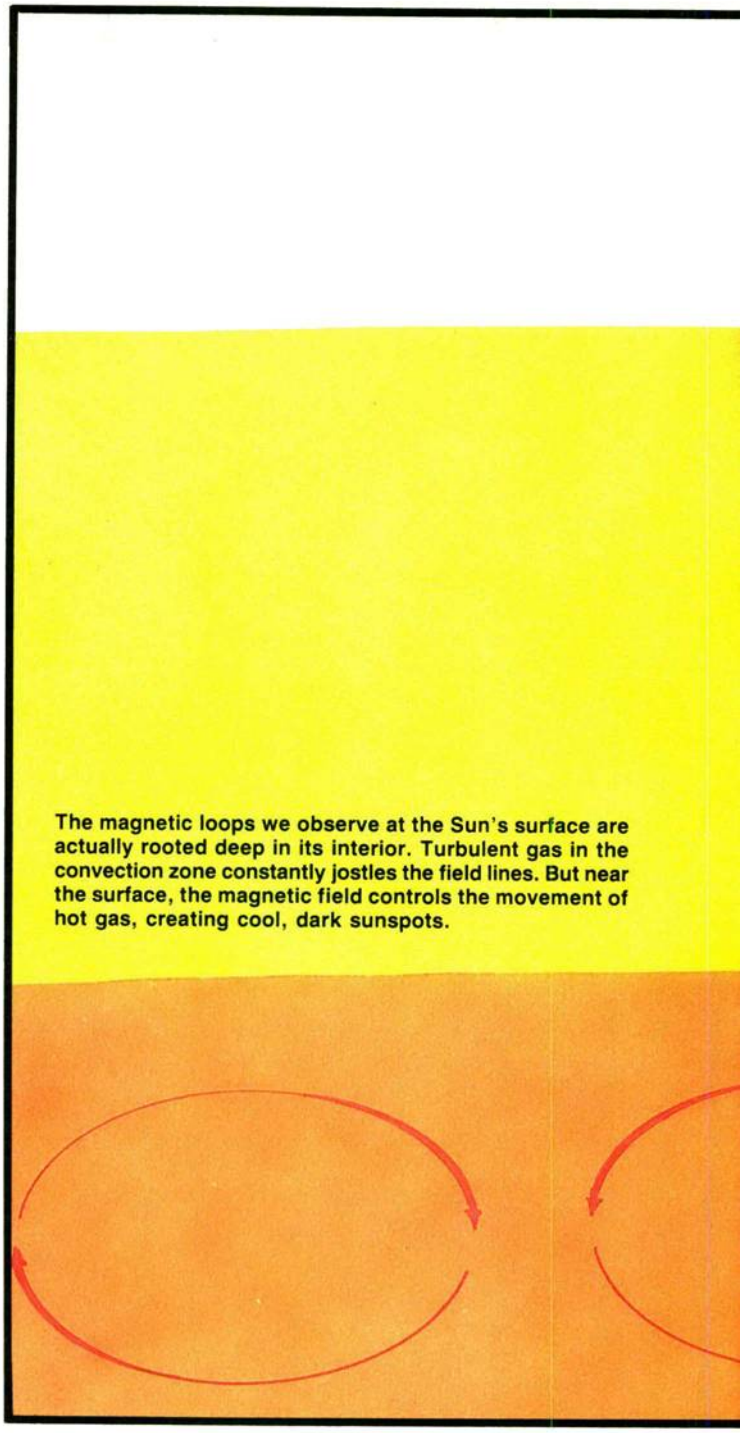

The Sun's Interior
Corona
Convection Zone
Radiation Zone
Core
Photosphere

All art by Thomas L. Hunt

experiments are being planned to verify this important conclusion, but it will be several years before the new experiments provide data.

During the last decade, astronomers have been using an entirely different class of detector to scrutinize the Sun. By watching the motions of material on the solar surface for extended periods, astronomers can determine if it tends to oscillate at particular frequencies. Observations indicate that material in the Sun does indeed have several frequencies at which it prefers to oscillate, or "ring." The existence of preferred periods in the motion of solar gas can be used to test mathematical models of the Sun's inner structure. Some of the periods are controlled by the structure deep inside the radiation zone surrounding the center of the Sun; other periods are controlled by the structure near the surface, in the convection zone. The rich spectrum of preferred oscillation periods allows researchers to tune in on processes occurring at different depths inside the Sun. The results suggest that our theoretical models of the convection zone are rather reliable. Although there are some discrepancies, they do not seem to be as contradictory as those in neutrino detector experiments. Matching observed periods with calculated periods is currently an active area of research in solar physics. It's done much the same way that geophysicists use the ringing of the Earth following an earthquake as a tool for peering inside our planet. There are, of course, no earthquakes on the Sun because no solid material exists to store up stress. Still, the analogy is a useful one. In the Sun, we believe the ringing is stimulated by the convective motion of hot upwelling gas. These motions occur constantly, so mechanical energy is continuously available (at least in the convection zone) to make the Sun oscillate. The better we can determine the preferred periods, the better we can tie down various theoretical models of the Sun's interior. We can do this with great precision by observing the Sun for long periods of time. The longest continuous observation of gas velocities on the Sun is 120 hours — a record held by the Bartol Research Foundation's solar observatory at the South Pole.

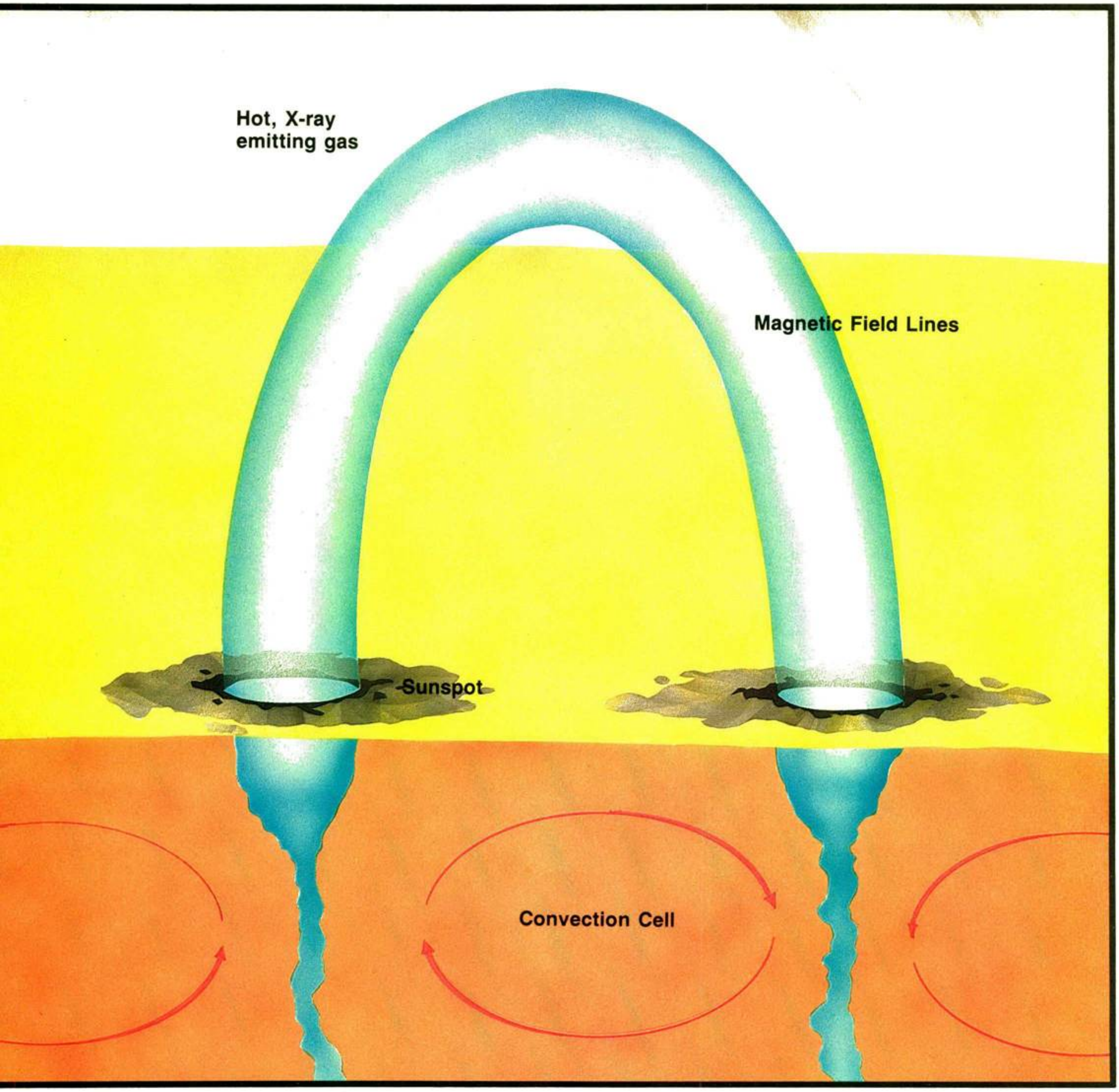
Another way to probe inside a star is to make use of some physical structure that extends from its interior out to its visible surface. A magnetic field line is just such an entity. The atmosphere of the Sun contains many locally strong magnetic fields. The fields are most prominent in so-called active regions, where they loop out of the solar surface at one location, arch upward into the atmosphere for thousands of kilometers, and then plunge back down into the Sun. Solar gas held in such a magnetic loop can reach temperatures up to millions of degrees and emit X-rays. If the magnetic field of the loop is strong enough, there may be dark patches — sunspots — at the regions where the loop breaks through the solar surface. The existence of sunspots indicates that the magnetic field has seriously hindered convection and interfered with its task of carrying heat up from the solar interior. In the surface layer of a sunspot, the magnetic field controls the gas and prevents it from moving about in its usual fashion. The existence of sunspots indicates that magnetic fields and convection in the Sun are tied together. In the surface of a spot, the magnetic field just happens to win out.



The magnetic loops we observe at the Sun's surface are actually rooted deep in its interior. Turbulent gas in the convection zone constantly jostles the field lines. But near the surface, the magnetic field controls the movement of hot gas, creating cool, dark sunspots.

For our purposes, the most interesting facet of these magnetic loops is that they do not begin at the surface, but penetrate deep into the convection zone. Various theories suggest that the magnetic fields we observe at the surface of the Sun are actually generated deep in its convection zone, near the region where the convection zone and the radiation zone meet. So the fields we see arching above the solar surface are actually rooted deep inside the Sun. A magnetic loop visible on the surface contains field lines that pass through a region where the Sun's convection is most strongly developed. At that depth, many hundreds of kilometers beneath the photosphere, the mechanical energy of convection is strong enough to dominate the magnetic field — a reverse of the situation in sunspots. Eddies in the convection zone jostle the field lines, pushing them back and forth. This pushing takes several hundred seconds to occur, and equals the length of time it takes a convection cell to complete one cycle in the Sun. So the magnetic field lines we see arching up through the solar surface are moving back and forth in response to the mechanical energy of convection. In that sense, the magnetic field lines at the surface of the Sun can be thought of as a kind of drill that bores beneath the photosphere and picks up oscillations from the depths where convection is strongest. Alternatively, we can think of the magnetic field lines as providing a channel for mechanical energy.

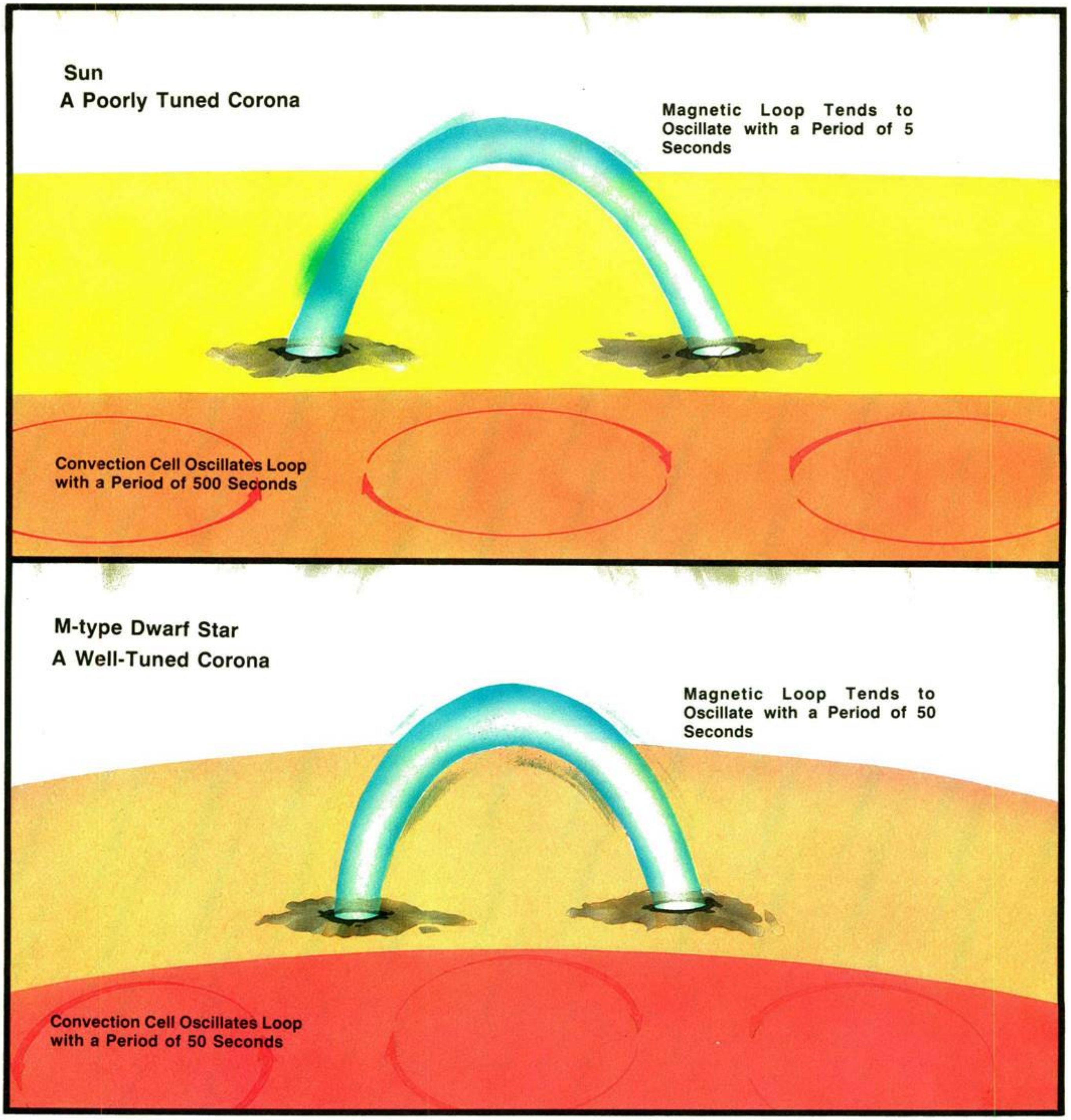
What happens to this mechanical energy when it reaches the surface? The answer to this question has a bearing on one of the longest-standing puzzles in solar physics: What heats the Sun's corona? The corona, the Sun's outermost layer, is a very tenuous hot gas with a temperature of a million degrees or so. Yet it lies directly above the Sun's surface, where the temperature is a thousand times lower. How can this hot gas exist? We won't find the answer by looking at the heat energy flowing up from the Sun's surface — heat cannot flow from cold gas to hot gas any more than water can flow uphill. The only possible source



of energy for the Sun's million degree outer atmosphere is mechanical energy. This energy can be deposited in the thin gas and thereby heats it up. So although mechanical energy removes only a small part of the total energy in the convection zone — carrying up about one percent of the heat — it is this minor constituent that plays an absolutely essential role in creating the super-hot solar corona.

In the Sun's atmosphere, only a small fraction of the available mechanical energy is actually tapped to heat the corona. Even in the most vigorous active region, no more than about 0.01 percent of the Sun's total energy output is converted into coronal heating. Why is the solar atmosphere so inefficient at tapping this abundant supply of mechanical energy? The answer can be best described by referring to a word used in the title of this article — "tuning." The magnetic loops in the atmosphere of the Sun are not well-tuned to the source of mechanical energy deep below the surface. The convection zone generates mechanical energy in motions with periods of several hundred seconds. These motions shake the magnetic field lines, forcing them to oscillate at similar periods. On the other hand, the loops in the solar atmosphere seem to be tuned for oscillations with much shorter periods — only a few seconds. According to recent calculations by James Ionson of NASA's Goddard Space Flight Center, if mechanical oscillations at a period of, say, 500 seconds are imposed on a loop which likes to oscillate at, say, 5 seconds, then only about one percent of the mechanical energy will be deposited in the loop.

But suppose we could find a star with magnetic loops in its atmosphere that preferred to ring at the same period as the oscillations produced by mechanical energy deep beneath the surface. In this case, Ionson's calculations suggest that the loop would get a much larger fraction of mechanical energy from the convection zone. In fact, under ideal conditions with perfectly matched periods, essentially *all* of the mechanical energy in the



Sun
A Poorly Tuned Corona
Magnetic Loop Tends to Oscillate with a Period of 5 Seconds
Convection Cell Oscillates Loop with a Period of 500 Seconds
M-type Dwarf Star
A Well-Tuned Corona
Magnetic Loop Tends to Oscillate with a Period of 50 Seconds
Convection Cell Oscillates Loop with a Period of 50 Seconds

convection zone could be deposited in the magnetic loops. In such a star, magnetic loops in the atmosphere would indeed be "tuning in" to what was happening in the star's interior. Of course, the convective motions wouldn't precisely match all the loops in the star's atmosphere, but in this ideal case they'd come pretty close.

Do such ideally tuned stars actually exist? Results from the Einstein X-ray satellite suggest the answer is yes. According to data published recently by Leon Golub of the Smithsonian Astrophysical Observatory, the coronas of certain cool dwarf stars (spectral type M) are emitting so strongly in X-rays that they must be receiving about one percent of the star's total energy output — 100 times the amount received by the Sun's corona. Models of convection suggest that the flow of mechanical energy is about one percent that of the heat energy. This ratio remains essentially constant in all dwarf stars, such as the Sun and the M dwarfs. M dwarfs appear to be highly efficient at extracting mechanical energy from their convection zones and depositing it in their coronas. Could this be an indication of magnetic loops ideally matched to tune in on the convection?

Again, there are some indications that the answer may be yes. The time it takes for convection to complete a cycle in M dwarfs is much shorter (only a few dozen seconds) than in the Sun. In addition, indirect evidence from studies of flares from M dwarfs suggests that magnetic loops in their atmospheres may tend to oscillate at longer periods than those in the Sun — possibly as long as a few dozen seconds. If further observations substantiate this evidence, it would seem that the atmospheres of M dwarfs really *are* tuning in to their own convection zones — a finding that gives us a previously unexplored window for probing the deep interiors of stars.

Dermott Mullan is an astrophysicist with the Bartol Research Foundation. His research interests include the effects and behavior of magnetic fields in stellar atmospheres.

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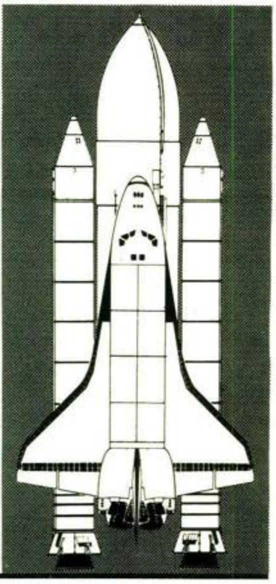

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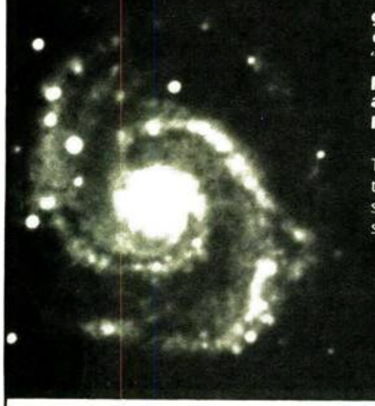

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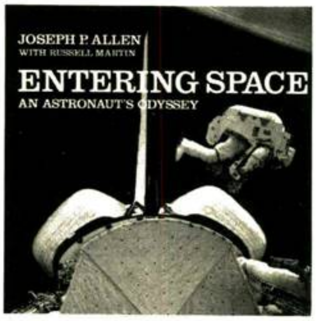

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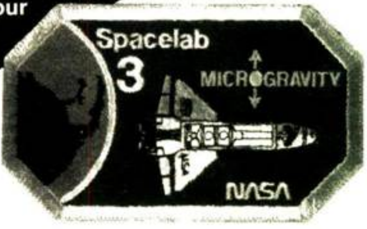

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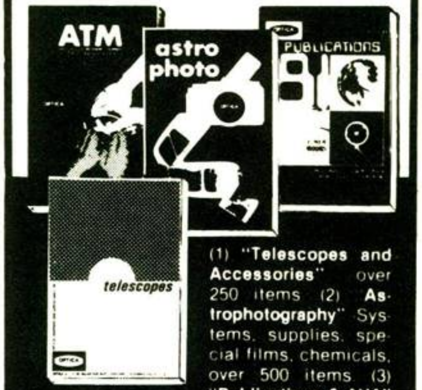

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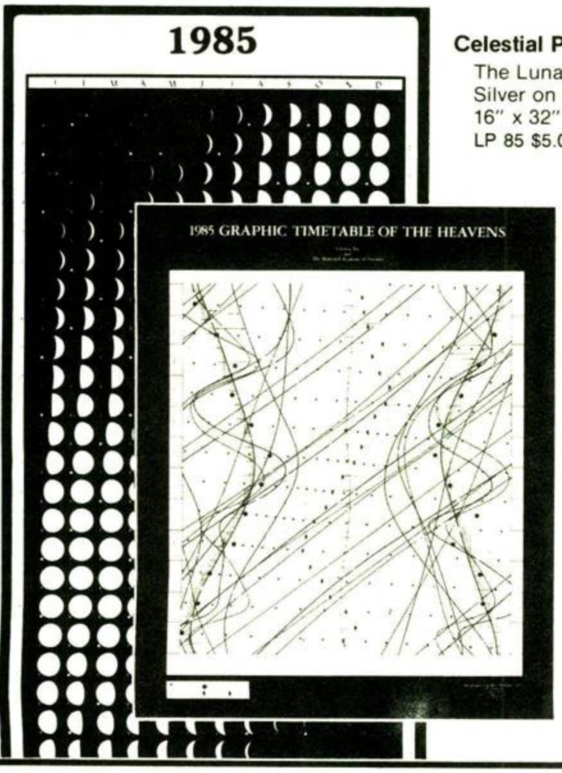

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Successful Schmidt Camera Photography

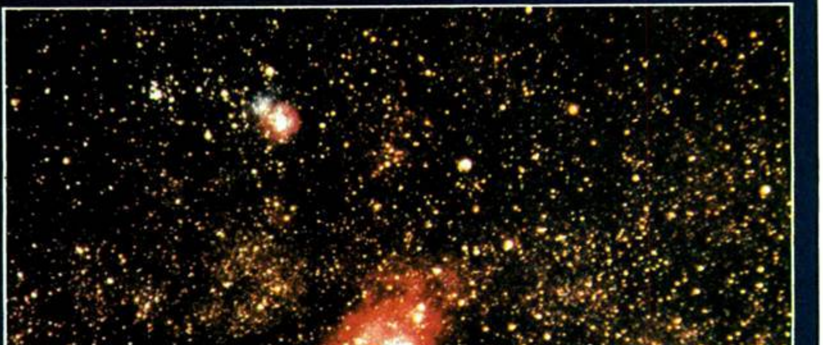
Photography in Astronomy

by
Val Akins

Of all the types of astronomical photography, Schmidt camera photography is perhaps the trickiest. It requires the same talents needed for making guided piggyback photos — precise polar alignment, carefully monitored guiding, and scratch-free developing and printing — but Schmidt photography presents the added difficulty of having to handle little pieces of film in the dark, out under the stars. With all of the potential problems involved in using a Schmidt camera, you'll want to minimize the risks as much as possible by practicing basic Schmidt camera techniques and by choosing the best film and method of processing for the results you desire.

Schmidt Photography

German optician Bernhard Schmidt invented his camera in 1930, and the "Schmidt" immediately impressed professional astronomers with its wide field, fast photographic speed, and razor-sharp optics. The camera consists of a long tube with a primary mirror at one end, a correcting plate at the other end, and a film holder about halfway in between. Commercial models, which use 35mm film, come in 4-inch, 5.5-inch, and 8-inch apertures.



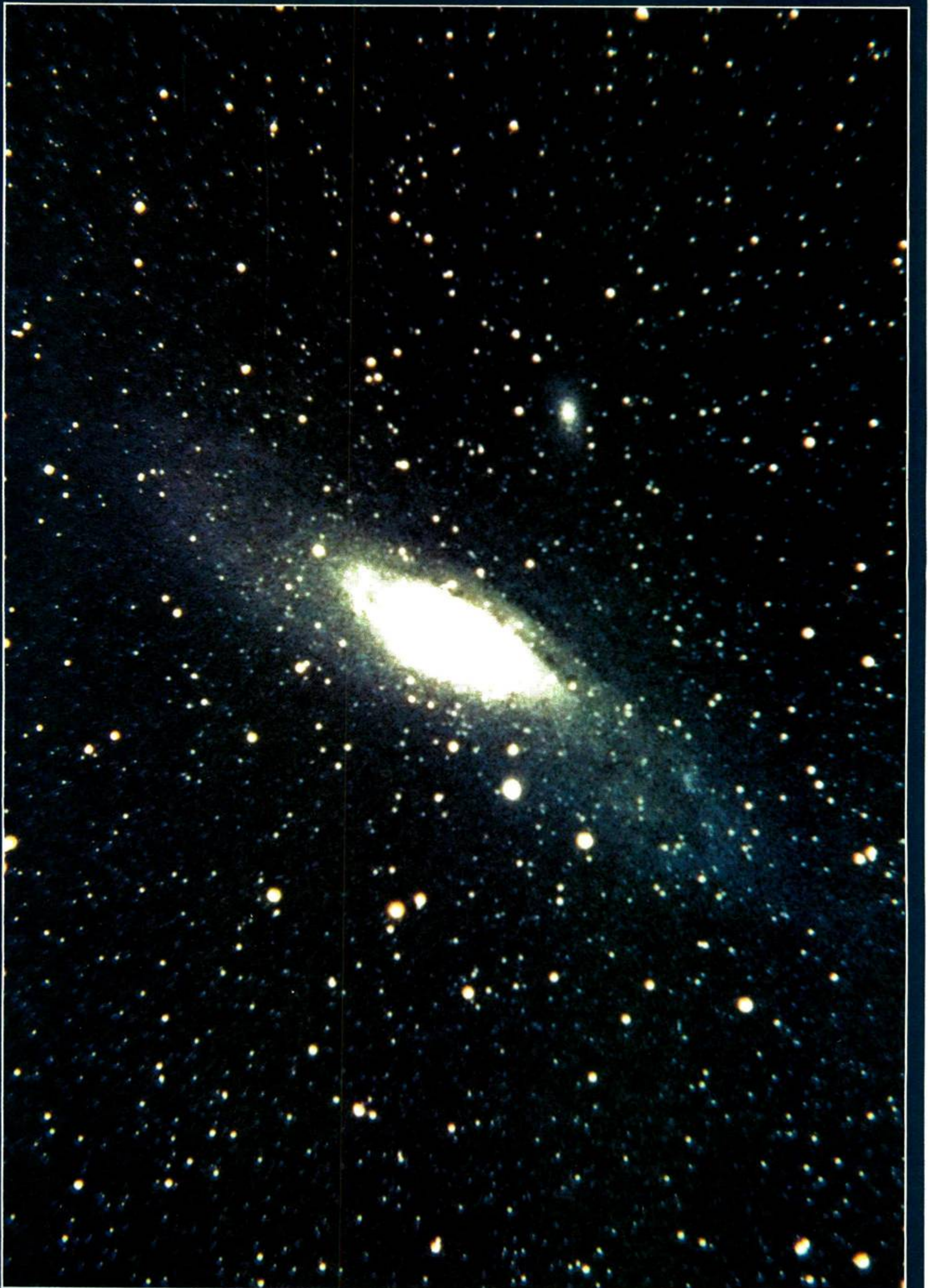
A 5.5-inch f/1.65 Schmidt camera and a 20-minute exposure on Fujichrome RD 100 recorded faint light from the Lagoon and Trifid Nebulae in Sagittarius. All photos in this article are by the author. They were developed as negatives and rephotographed to enhance contrast and improve color balance.

Serious sky photographers favor Schmidt cameras for two main reasons. First, the Schmidt's fast f/ratios of f/1 to f/3 allow for very short exposures: 1 to 15 minutes for most subjects as compared with 10 to 120 minutes for a normal f/5 to f/10 telescope optical system. This reduction in guiding time reduces guiding errors and other problems arising during a long exposure. Second, Schmidt cameras cover a large area of sky which makes it possible to photograph an entire large object — like the Andromeda Galaxy or Orion's Belt — in a single frame. With fine-grain film, small pieces of the original negative can also be enlarged to make 5" x 7" or 8" x 10" prints which hold together and look pleasing to the eye. In short, Schmidt cameras produce pictures you couldn't take with an average telescope setup.

But operating a Schmidt camera can be complex. First and foremost you need a *dark* sky. Then you must perform the same tasks necessary with other cameras for astrophotography: equatorially mount and polar align the camera, affix a guidescope of sufficient focal length with illuminated cross hairs for guiding, and track a star for the duration of the exposure while countering the Earth's rotation — and if your back yard is not your observing site, you've got to transport everything to a dark site. But, in addition, the Schmidt camera requires that a film chip be loaded into the camera before an exposure and removed afterward. A changing bag must be used to keep the film in the dark, except during the exposure itself. (For detailed information on using a Schmidt camera, see "Schmidt Cameras," ASTRONOMY, November 1976 and "An Inexpensive Roll Film Holder for Schmidt Cameras," ASTRONOMY, February 1984.)

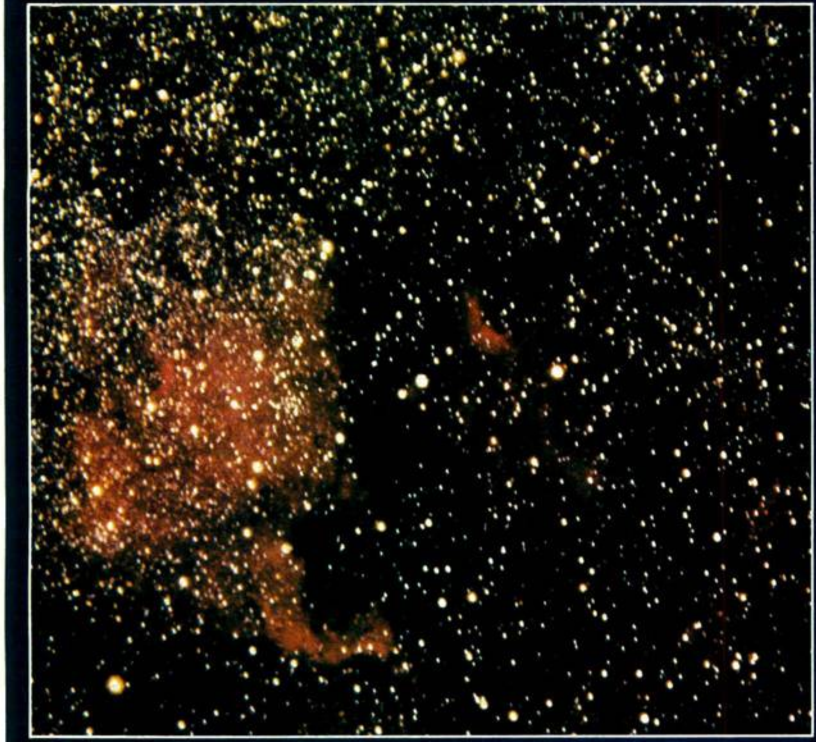
Shooting Straight Slides

Now let's suppose you want to take a color picture of the Rosette Nebula or an even fainter object like the California Nebula in Perseus. With an ordinary telescope, you would have to expose for



With the 5.5-inch Schmidt, a 15-minute exposure on RD 100 captured M-31's tenuous spiral arms and bright yellowish core.

A 20-minute exposure on RD 100 was sufficient to record the reddish light from the North America Nebula in Cygnus.



an hour or more to collect enough light. Schmidt cameras cut down on exposure time and make using color slide films pleasurable. They are optically fast enough to eliminate reciprocity failure as a serious problem. (Reciprocity failure is the name given to the way films become slower and slower as exposure times increase; it is worse with color films than with specially-made black and white 103a emulsions.) The short focal length of Schmidts means guiding tolerances are less severe than with a long-focal-length telescope. With an adequate guide telescope mounted atop the Schmidt, or your telescope's optical system with Schmidt mounted on top, you need not keep a guide star "dead centered" as with a telescopic shot. This means it's easier to find a suitably bright one.

From a reasonably dark site, color slide film exposed for only 3 to 10 minutes will record faint nebulae and produce an eye-pleasing, though not very contrasty image. This lets you take beautiful color shots of many deep-sky objects. But fast color film is fairly grainy stuff, so if you're interested in recording smaller objects for later enlargement, it's best to stay with black and white films.

Technical Pan: Fine-Grain Enlargability

During the late 1970s, Kodak introduced a new emulsion for black and white fine-grain photography called SO-115. It has since been renamed Technical Pan 2415 and further improved. It is now an exceedingly useful film for astrophotography. Technical Pan 2415 offers high contrast and, compared with old standard 103a films, incredibly fine grain for good resolution. It is not especially fast, which is a problem for most telescopic photography where f/ratios run in the f/5 to f/10 range. But since Schmidt cameras operate at focal ratios of f/1 to f/3, the exposure times for photographs on 2415 are reasonably short. Fine photographs of faint nebulae can be made in exposures of 5 to 10 minutes — something that could never be done with ordinary telescopic optical systems which are painfully slow by comparison.

Particularly useful with 2415 film are filters, which permit you to record deep-sky objects even in moderately light-polluted areas. If you want to photograph nebulae, get yourself a Wratten #25A red gelatin or glass filter. (Make sure that it fits over your Schmidt film holder.) These filters are sold, ready to mount, by several manufacturers. Because the filter transmits only red light, you'll need to increase exposure times by 50% to 100% when using it. This translates to 10 to 20 minute exposures, which are still bearable. Several manufacturers offer special types of nebular filters which transmit narrow bandpasses, letting you record the light from reflection nebulae or galaxies. You may have to mount these filters yourself, however.

After obtaining a few good ones, you'll discover that you can enlarge 2415 negatives to 25x or 40x, or even 50x, and retain a reasonably crisp image of small objects in the field — an impossibility with color films and most black and white emulsions. With a Schmidt camera, Technical Pan film, and an enlarger capable of super-enlargements, you can record detail in the galaxy M-82 or the center of the Virgo cluster with an exposure of only 5 minutes.

Developing Slide Film as a Negative

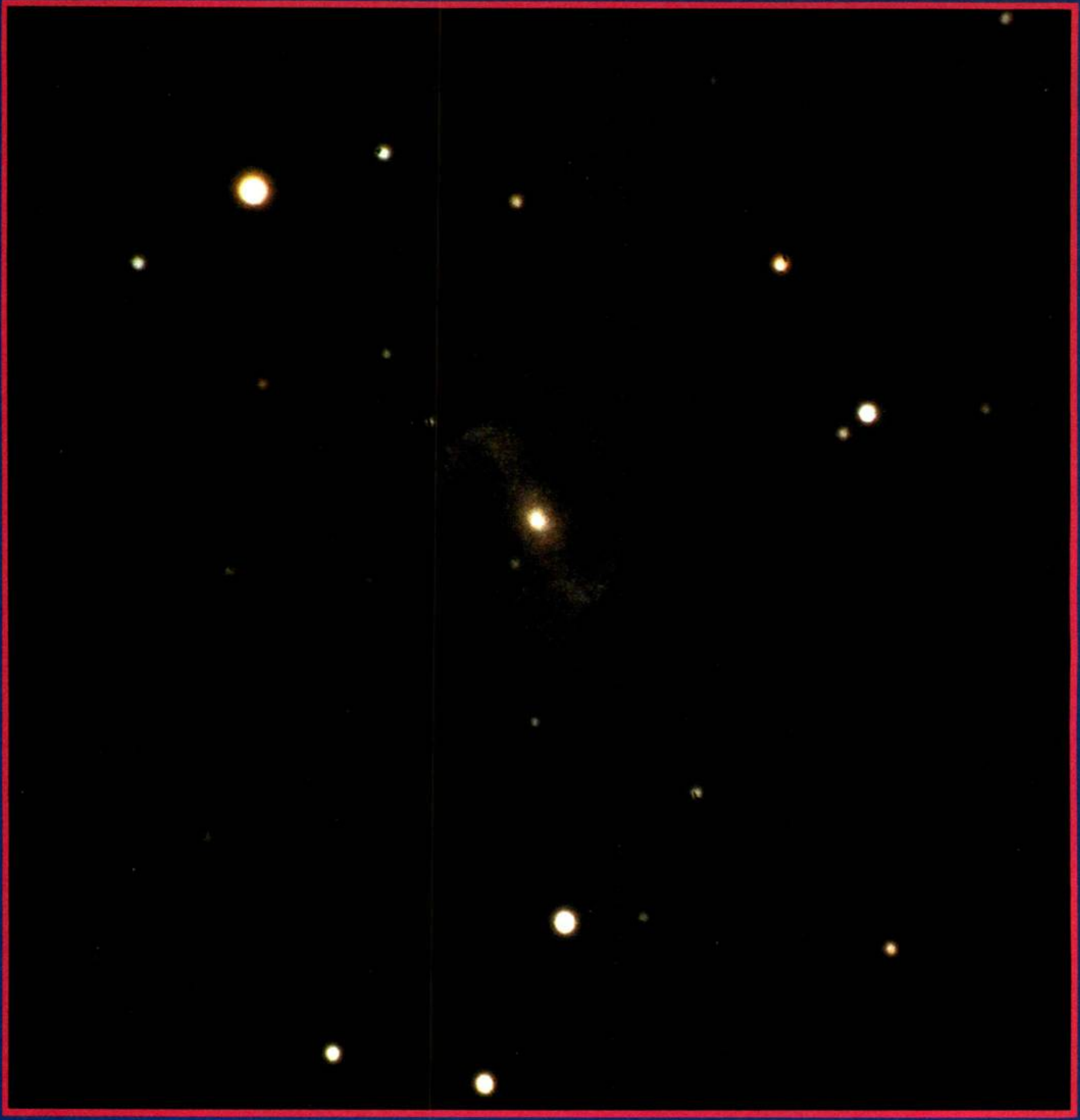
One particularly valuable technique for Schmidt camera photography alleviates the low-contrast look of straight color shots. To increase its contrast and speed, process your slide film as if it were color negative material, using Kodak's Flexicolor chemistry (C-41). I recommend using Fujichrome 100 film, which seems to respond particularly well to red light.

For the best results, you'll have to change the normal developing times for your favorite color emulsions. During the first step, develop the film for 4 minutes rather than the recommended 3½ minutes for daylight shots, making sure that the temperature remains at 100° F. Then give the film 2½ minutes in blix — a combination of bleach and fixer — rather than the normal 6-minute treatment. For the remaining times, follow Kodak's recommended times.

After developing, you should have negatives with reasonably good contrast and color balance, though without the orange mask typical of color negatives. To begin, get a few color prints made from your best negatives at a reliable photo shop. Next, convert those prints into slides. Load your camera with a high resolution color film (like Kodachrome 64 or Kodachrome 25) and rephotograph the prints in daylight with your camera set according to its light meter. The resulting slides will look dramatically better than a normal straight slide, with visibly more contrast. If you have problems with the color balance, you may need to insert a color compensating filter over the camera lens before rephotographing the prints.

Schmidt camera photography is a rather sophisticated exercise in backyard astronomy. If you've mastered the problems inherent in operating the camera — loading and unloading the film, guiding, and developing — then you're probably ready to experiment with new and even more challenging aspects of Schmidt photography. These are demanding processes, but by successfully shooting color slides, cleverly enlarging bits of 2415 negatives, or rephotographing slides originally developed as negatives, you can make the most of recording the sky with one of Bernhard Schmidt's wonderfully fast cameras.

Val Akins is an amateur astronomer who teaches astrophotography at Saddleback College, in Mission Viejo, California.

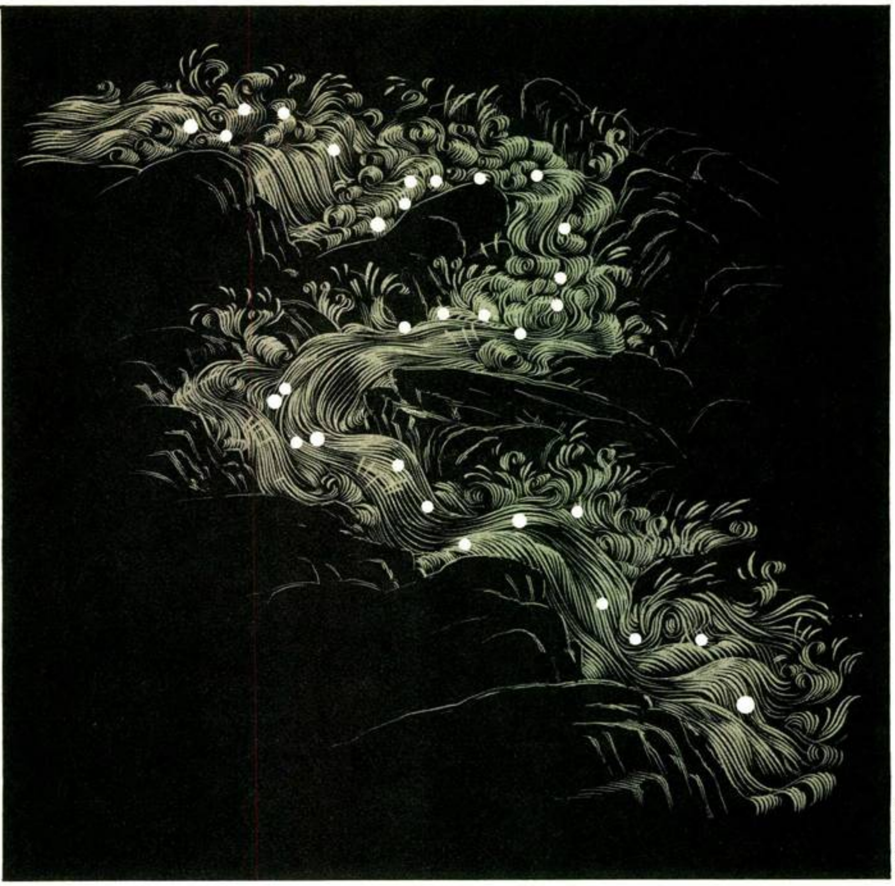


Above: Though it glows at only 11th magnitude, NGC-1300 is one of the finest examples of a face-on barred spiral galaxy. Small telescopes show a bright core surrounded by undefined haze, which large telescopes reveal to be the galaxy's arms. Photo by John Gleason. Far left: The planetary nebula NGC-1535 shows a strong bluish-green color, often the only way to distinguish its starlike disk from ordinary field stars. Photo by Martin C. Germano. Left: One of the finest double stars in Eridanus is 32 Eridani, easily separable with small scopes.

Eridanus

Eri

Eridani



Keith Ward

Eridanus the River is a long, twisting constellation which begins near Orion's bright star Rigel and winds down to Achernar, some 49° to the south. Eridanus is not striking to the naked eye; it lies away from the plane of the Milky Way and contains relatively barren starfields — but it also harbors great numbers of faint galaxies.

The brightest collection of galaxies in Eridanus lies near its center. **NGC-1300** is one of these — a magnitude 11.3 galaxy measuring 6.0′ x 3.2′ across, making it easy to find with small telescopes. It appears as an elongated smudge with a sharply brighter center, surrounded by a large diffuse halo of nebulosity. Dark skies and large optics show NGC-1300 as one of the finest face-on barred spiral galaxies in the sky with two distinct arms emanating from a bright central bar. A nebular filter attached to your scope will help you see subtle details, especially when skies are light-polluted.

Southwest of NGC-1300 is **NGC-1232**, another face-on spiral. A type Sc galaxy, it is one of the "many-armed spirals" which have more than the normal two, three, or four spiral arms. Its magnitude 10.7 light spreads over an area of 7.0′ x 6.0′, making its surface brightness fairly low. This galaxy shows up in 4-inch reflectors as a circular nebulosity without much central condensation. NGC-1232's spiral arms are very difficult to observe, although a 16-inch reflector at moderate power may show hints of bright arms running alongside thin dark lanes. Nearby is another multiple-arm spiral, **NGC-1187**. At magnitude 11.3, this galaxy is slightly fainter than NGC-1232, but it covers only 5.5′ x 4.0′ of sky, and therefore looks equally as bright in the telescope.

Located several degrees east of NGC-1187 are two more of Eridanus' many galaxies. **NGC-1325** is a rather faint Sb-type spiral, visible in 4-inch telescopes as a small oval smudge of light. It shines with the light of a magnitude 12.5 star, covers a 3.0′ x 1.0′ area, and is easily recognized by a ninth-magnitude star just off its northeastern edge. Nearby is the faint galaxy **IC 1953**, a magnitude 12.5 barred spiral, a perfect circle measuring 2.4′ across. It is faintly visible in 6-inch telescopes as a fuzzy spot of white light, showing little or no central condensation.

Several degrees southeast of the NGC-1325 area is the long period variable star **T Eridani**. This star is fascinating to watch as it fluctuates between magnitudes 7.4 and 13 during its 252-day cycle. At maximum brightness, T Eridani is a bright, easily-observed rosy red star in binoculars or small telescopes; at minimum, it glows weakly at less than 13th magnitude and is difficult to identify without a special finder chart.

Toward the eastern fringes of Eridanus lies a pair of little galaxies, **NGC-1531** and **NGC-1532**. The brighter of the two, NGC-1532, is a 12th magnitude Sb-type spiral. It is nearly edge-on to our line of sight — measuring 5.0′ x 1.0′ — and is fairly easy to find because of its high surface brightness. A 6-inch telescope under dark skies shows a silvery sliver of light without detail. A 12-inch scope, however, lets you see that NGC-1532's nucleus is slightly brighter than the rest of the galaxy, with an elongated halo evenly decreasing in brightness as it moves away from the spiral's center. Large backyard telescopes also show NGC-1531 — a tiny 13th magnitude elliptical located just 1.6′ to the northwest. This galaxy appears stellar at low powers (it measures only 30″ x 18″ across) and reveals no detail in backyard telescopes.

Much brighter than NGC-1531 is the fine barred spiral **NGC-1291**. This galaxy covers 5.0′ x 2.0′ and shines at magnitude 10.2. A 2-inch telescope will show this object as an oval patch of light, but for northern observers its southerly declination of −41° may cause problems for those without a clear, dark southern horizon. Under good conditions, a 10-inch telescope shows NGC-1291's very bright core, surrounded by a uniformly illuminated envelope of fainter nebulosity. Owners of large telescopes and observers at low latitudes may see some structure in this galaxy.

Two bright galaxies lie in the northern part of Eridanus, within easy viewing reach of Northern Hemisphere telescopes. The first is **NGC-1337**: a 12th magnitude edge-on Sc-type spiral. Though low in total magnitude, NGC-1337's surface brightness is great because the galaxy is turned sideways to our line of sight. NGC-1337 measures 5.4′ x 0.9′ and is visible in large finder telescopes under dark skies. A 6-inch reflector shows a

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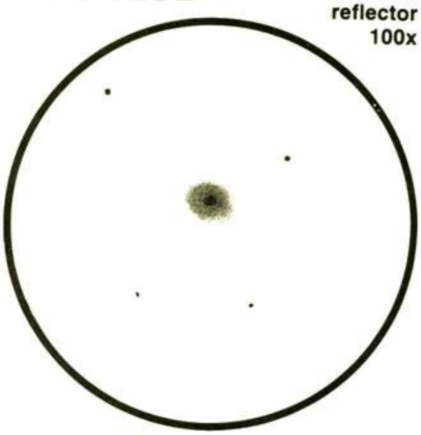
NGC-1232

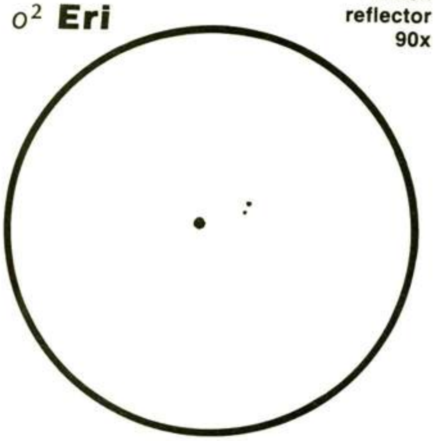
8-inch reflector 100x



Sketch by David J. Eicher

o^2 Eri

4-inch reflector 90x



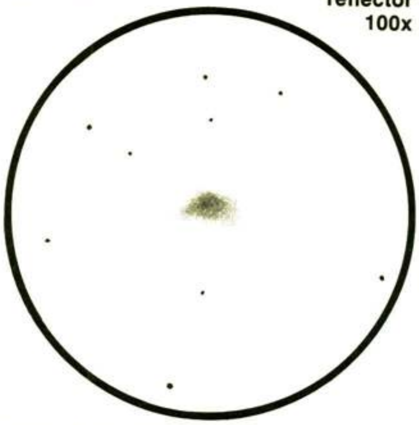
Sketch by Jim Mullaney

bright, sharply-defined core, enclosed in a spindle-shaped nebulosity. Another galaxy to note is NGC-1084, an 11th magnitude Sc-type spiral. Its dimensions measure 2.1′ x 1.0′, and its bright middle shows up well in a 4-inch telescope. Larger telescopes reveal a roundish halo of faint light which is the galaxy's spiral arms.

Tau^4 Eridani is a bright double star encircled by galaxies NGC-1232,

NGC-1300

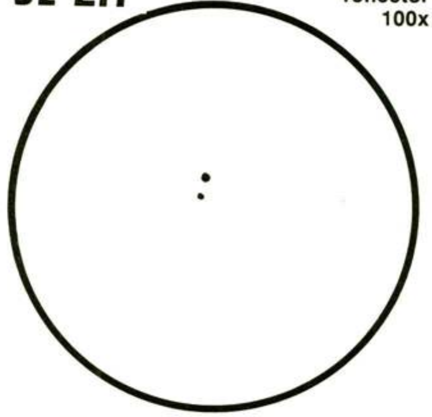
8-inch reflector 100x



Sketch by David J. Eicher

32 Eri

8-inch reflector 100x

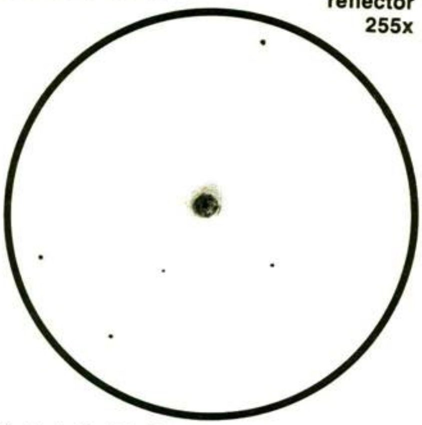


Sketch by Jim Mullaney

NGC-1300, NGC-1325, and IC 1953. At magnitudes 4 and 10, its components are widely separated in brightness, but the 5.7″ gap between them allows small telescopes at high power to split them. Another double star for small telescope viewing is **32 Eridani**, whose magnitude 5 and 6 members are separated by 6.9″ in p.a. 347°. This star offers excellent color contrasts: the primary shines golden-yellow, while the companion star is sparkling white.

NGC-1535

8-inch reflector 255x



Sketch by David J. Eicher

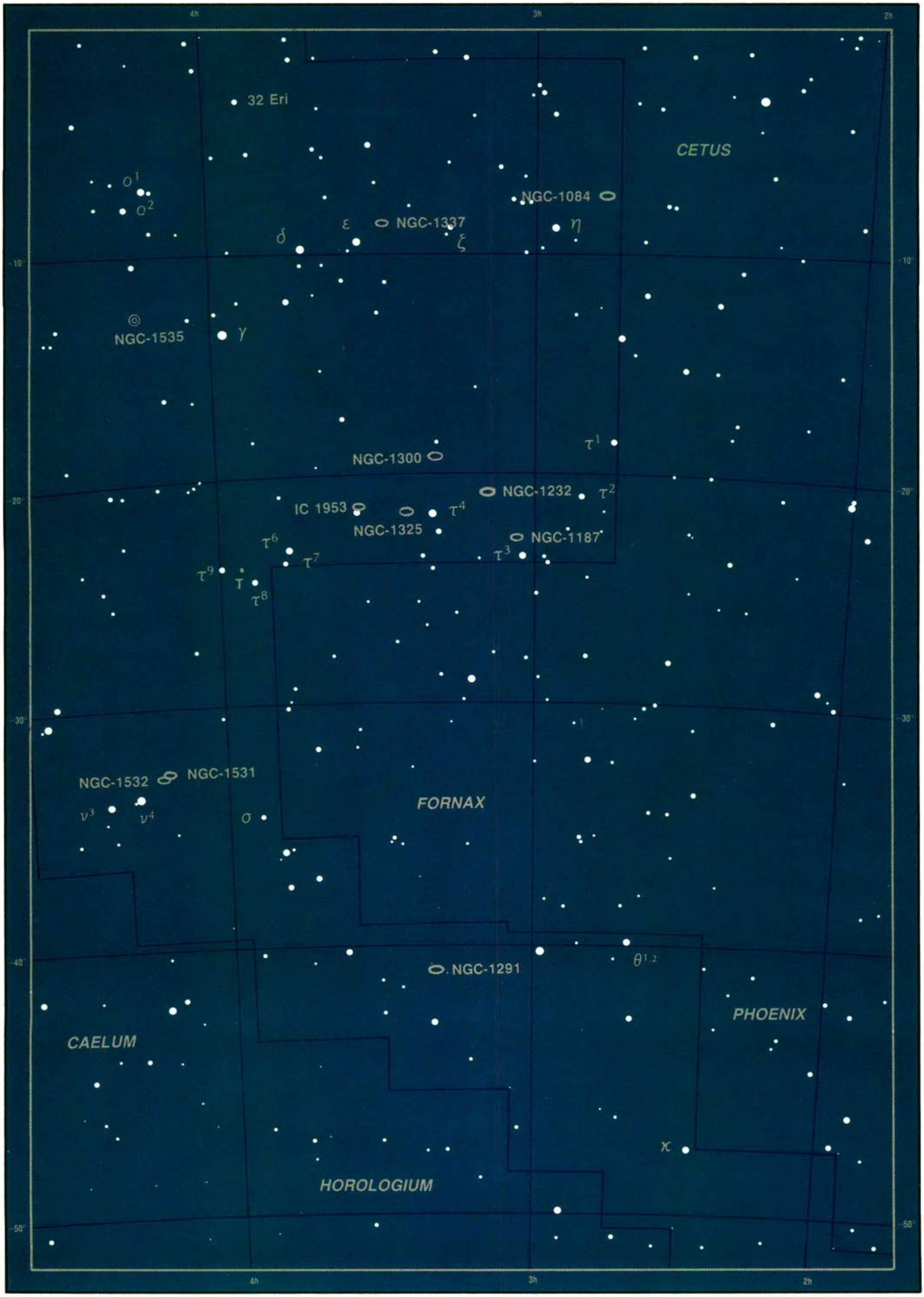
A remarkable triple star system, located in the northeastern part of the constellation, is **Omicron^2 Eridani**. The system contains two stars, separated by 82.8″ in p.a. 105°, which shine at magnitudes 4.5 and 9.5. The fainter star is one of the most easily observed white dwarf stars. The secondary of this wide pair is itself a double star, harboring an 11th magnitude red dwarf star — again, one of the best examples of such a star for small telescopes. The close pair is separated by 7.6″ in p.a. 347°, and is easily split with high power under good seeing conditions. Omicron^2 Eridani is only 5 parsecs away — the eighth closest naked-eye star in the sky — and has a large proper motion of some four arc-seconds per year.

Though small, the planetary nebula **NGC-1535** is one of the best for observing the characteristic color found in these objects. At ninth-magnitude, NGC-1535 measures only 20″ x 17″ across, but its bright disk shows a strong and unmistakable bluish-green hue in any telescope. In fact, this distinguishes it as a nebula and not a field star: high-power backyard scopes reveal the nebula's magnitude 11.5 central star and show the disk as clearly nonstellar in appearance.

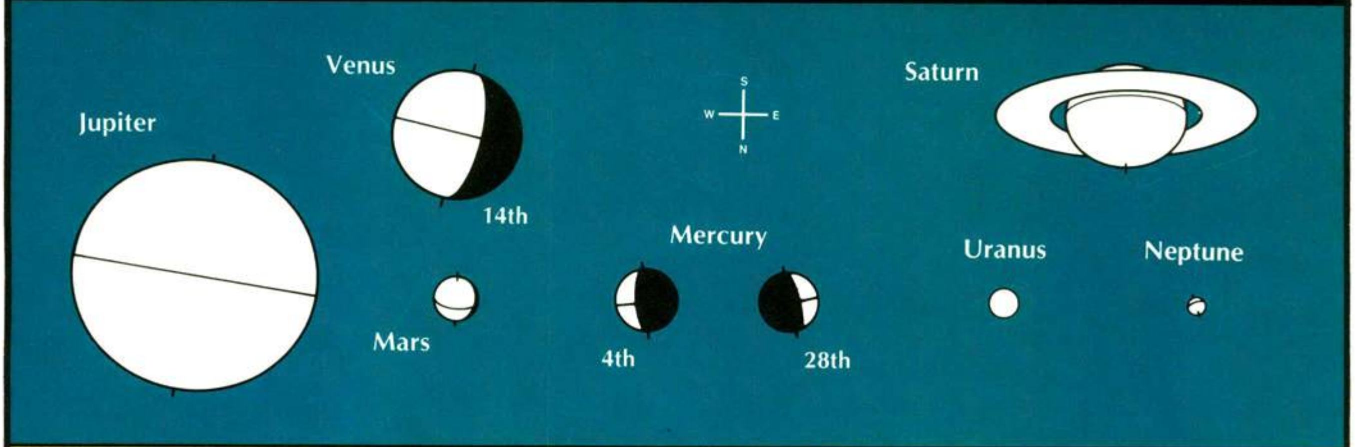
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-1084		§	0h 45.9m	− 6°54′	11.3	2.1′x1.0′	Sc(s)
NGC-1187		§	3h 02.6m	−22°52′	10.9	5.5′x4.0′	SBbc(s)
NGC-1232		§	3h 09.8m	−20°35′	10.5	7.0′x6.0′	Sc(rs)
NGC-1291		§B	3h 17.3m	−41°06′	9.4	5.0′x2.0′	SBa
τ^4		★^{2}	3h 19.5m	−21°44′	4.0, 10.0	5.7″	
NGC-1300		§B	3h 19.8m	−19°24′	11.1	6.0′x3.2′	SBb(s)
NGC-1325		§	3h 24.5m	−21°32′	12.3	3.0′x1.0′	Sb
NGC-1337		§	3h 27.9m	− 8°24′	12.3	5.4′x0.9′	Sc(s)
IC 1953		§B	3h 33.6m	−21°29′	12.3	2.4′x2.4′	SBbc(rs)
T		LPV	3h 50.5m	−24°57′	7.4↔13	252d	
32		★^{2}	3h 54.2m	− 2°57′	5.0,6.0	6.9″	
NGC-1531		§	4h 12.0m	−32°51′	12.8	0.5′x0.3′	?
NGC-1532		§	4h 12.1m	−32°52′	11.5	5.0′x1.0′	Sab(s)
NGC-1535		■	4h 14.5m	−12°44′	10.8	20″x17″	
o^2		★^{3}	4h 15.4m	− 6°56′	4.5,9.5,11.0	82.8″,7.6″	

H = Hubble classification type for galaxies

★^{2}	*Double Star*
★^{3}	*Triple Star*
LPV	*Long Period Variable*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*

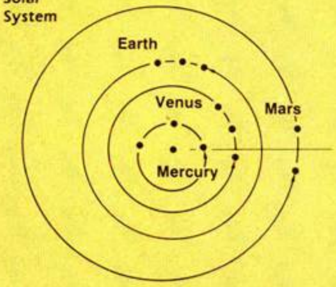

4h
3h
2h
32 Eri
CETUS
o^1
o^2
NGC-1084
η
ε
NGC-1337
δ
ζ
-10°
NGC-1535
γ
τ^1
NGC-1300
NGC-1232
τ^2
-20°
IC 1953
τ^4
NGC-1325
τ^6
NGC-1187
τ^7
τ^3
τ^9
T
τ^8
-30°
NGC-1532
NGC-1531
ν^3
ν^4
σ
FORNAX
-40°
NGC-1291
$\theta^{1,2}$
PHOENIX
CAELUM
χ
HOROLOGIUM
-50°

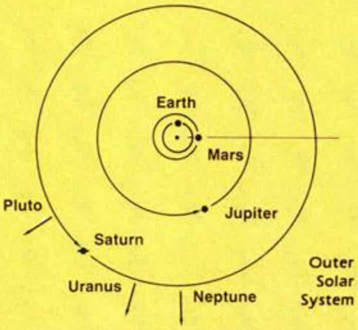
Planetary Data December 1984


Jupiter
Venus
14th
Mars
S
W
E
N
Mercury
4th
28th
Saturn
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−27.8	32.5′	—	0.99	—	—	248°59.2′	16h 30.0m	−21°49.9′
		15	−27.8	32.6′	—	0.98	—	—	263°12.3′	17h 31.3m	−23°16.7′
		31	−27.8	32.6′	—	0.98	—	—	279°30.4′	18h 42.3m	−23°05.3′
Mercury	☿	1	−0.1	7.5″	46%	0.90	0.35	4°01.5′	269°09.6′	17h 59.3m	−25°21.1′
		15	4.6	9.9″	1%	0.68	0.31	85°19.9′	261°41.4′	17h 27.6m	−21°18.2′
		31	−0.1	7.2″	54%	0.94	0.38	171°52.5′	256°41.4′	17h 06.1m	−20°31.3′
Venus	♀	1	−4.1	15.8″	72%	1.06	0.73	354°19.1′	289°52.3′	19h 30.5m	−24°08.9′
		15	−4.2	17.3″	68%	0.96	0.73	16°36.2′	306°22.5′	20h 40.3m	−20°38.8′
		31	−4.3	19.6″	62%	0.85	0.73	42°10.2′	324°42.5′	21h 53.1m	−14°34.8′
Mars	♂	15	0.8	5.8″	90%	1.61	1.39	359°28.3′	321°40.4′	21h 40.5m	−15°13.0′
Jupiter	♃	15	−1.9	32.6″	100%	6.04	5.16	292°06.5′	287°06.5′	19h 17.3m	−22°29.1′
Saturn	♄	15	0.6	15.4″	100%	10.74	9.91	230°07.9′	232°30.4′	15h 25.4m	−16°35.4′
Uranus	⛢	15	5.7	3.5″	100%	20.02	19.05	253°55.0′	253°51.1′	16h 53.0m	−22°32.9′
Neptune	♆	15	8.0	2.2″	100%	31.23	30.26	271°06.1′	270°22.1′	18h 04.6m	−22°19.4′
Pluto	♇	15	13.8	0.1″	100%	30.40	29.79	212°26.4′	213°23.4′	14h 29.5m	2°35.4′

Inner Solar System


Earth
Venus
Mars
Mercury

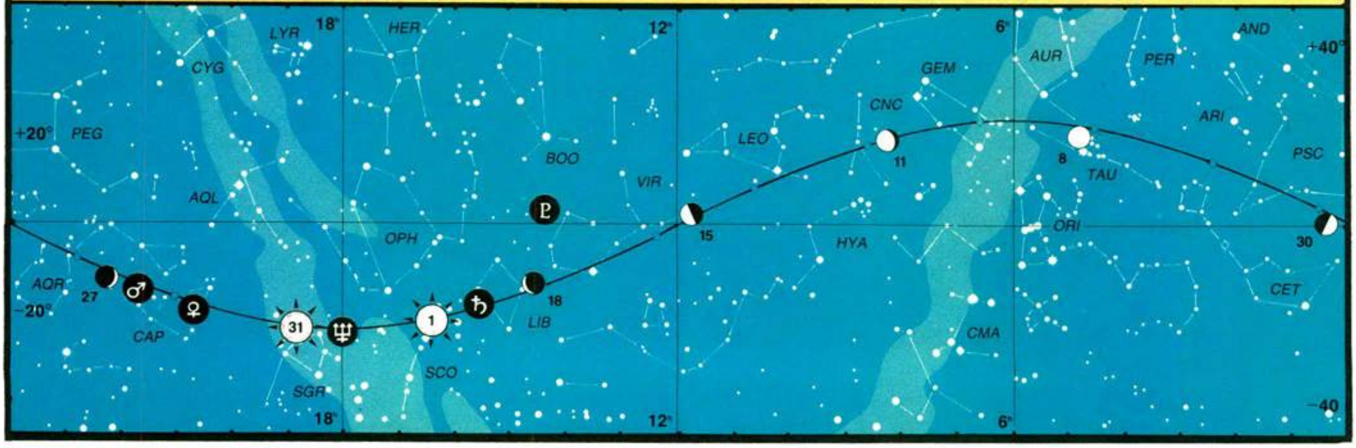

Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune

Outer Solar System

Moon Data

Full Moon . . . . Dec. 8 at 10:53
Last Quarter . . . . Dec. 15 at 15:25
New Moon . . . . Dec. 22 at 11:47
First Quarter . . . . Dec. 30 at 5:27
Full Moon . . . . Jan. 7 at 2:16

Apogee: Dec. 2 at 15:26 . . . . . 404,817 km.
Perigee: Dec. 18 at 9:56 . . . . . 368,390 km.
Apogee: Dec. 30 at 12:16 . . . . . 404,332 km.


LYR
18°
HER
12°
6°
AUR
AND
+40°
CYG
GEM
PER
CNC
ARI
+20°
PEG
LEO
11
8
TAU
PSC
BOO
AQL
VIR
♇
15
OPH
HYA
ORI
30
AQR
27
♂
♀
18
CET
−20°
31
♆
1
♄
LIB
CMA
CAP
SCO
SGR
18°
12°
6°
−40

The Double Cluster in Perseus is an unusual pairing of two open star clusters. Faintly visible to the naked eye under dark skies, the clusters "come alive" in binoculars and small telescopes. Photo by Sheldon Faworski, who used a 5-inch f/5 refractor, and a 25-minute exposure on Ektachrome 400 pushed to ISO 800.

Mercury

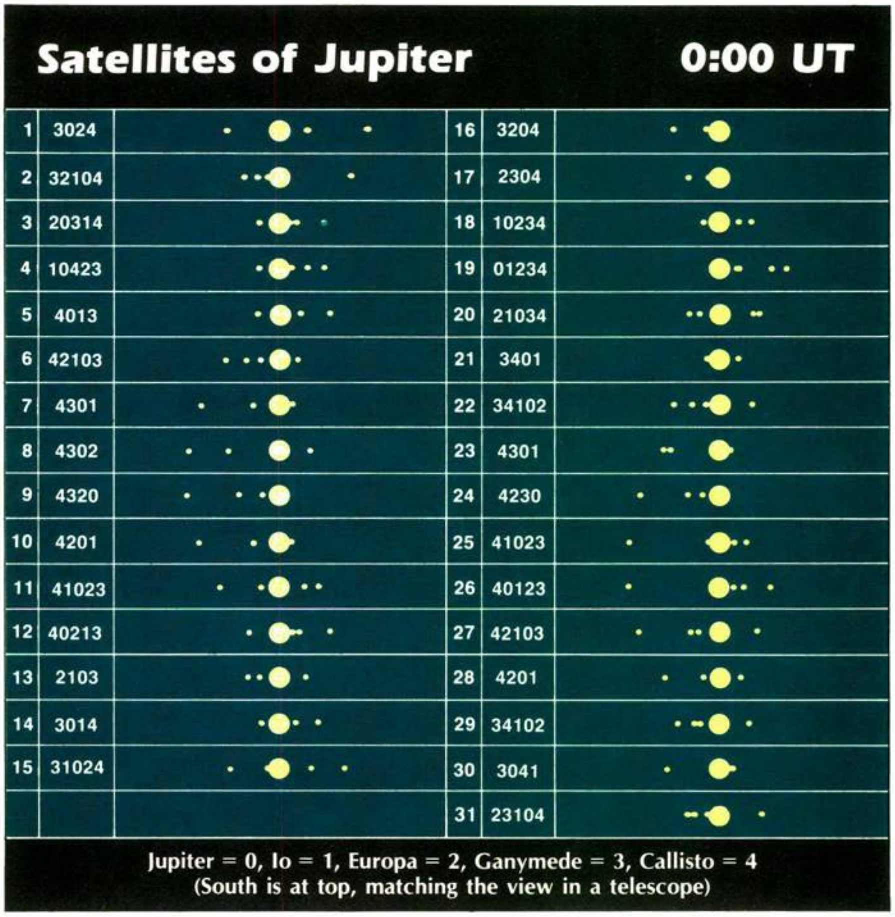
Mercury will be in view twice this month; it ends a poor apparition in the evening sky during the first week of December, then passes through inferior conjunction on the 14th. By about the 20th, start looking for it in the morning sky, low in the southeast just before sunrise.

On the 31st, 45 minutes before sunrise, it will be almost 10° high and shining at magnitude −0.1. In a telescope, you can observe its apparent diameter changing from 9.4'' on the 20th to 7.2'' on the 31st.

Venus

Venus is the brightest object in the evening sky (apart from the Moon, which passes 3° south of it on the 25th), a brilliant point of light in the southwest. Between now and next April, Venus grows much larger in apparent size and steadily brightens as it nears inferior conjunction.

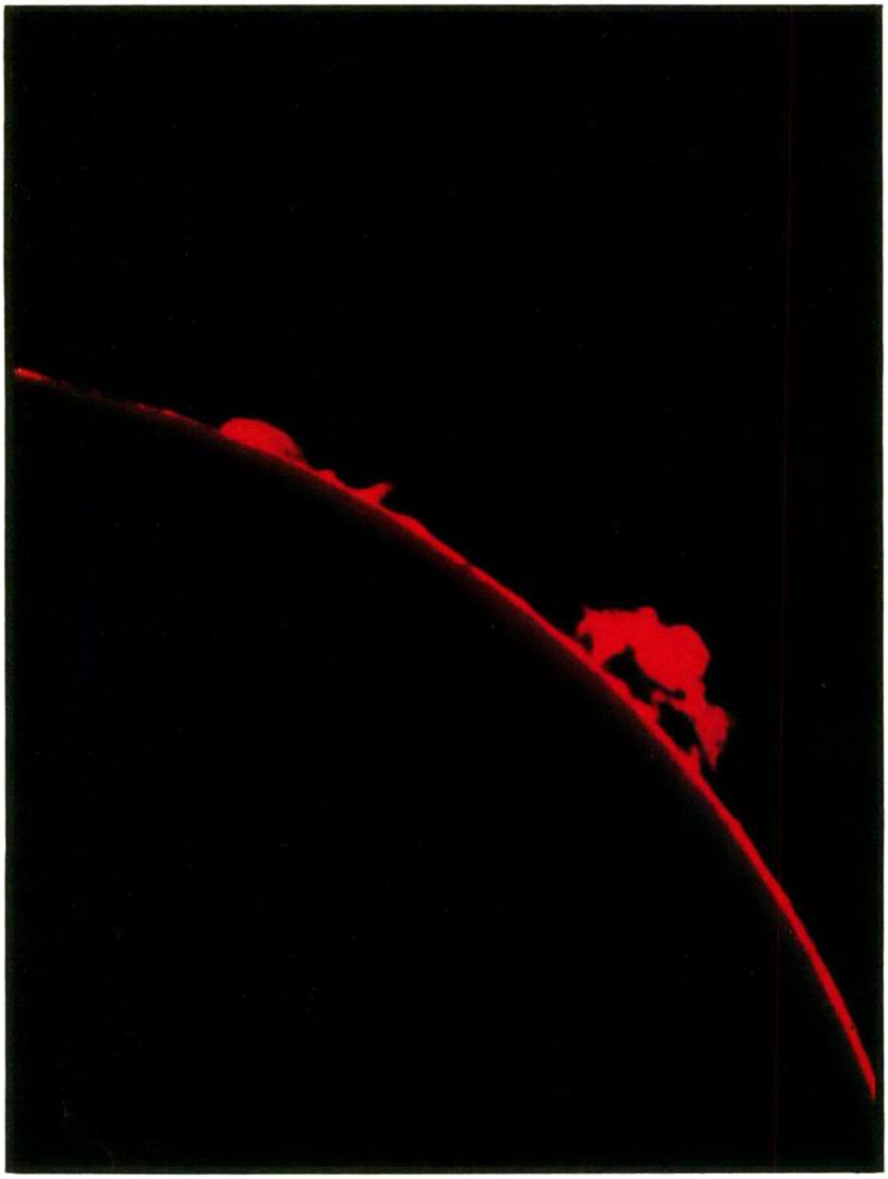
Try making a series of telescopic sketches, all to the same scale, which



Satellites of Jupiter 0:00 UT

1	3024	16	3204
2	32104	17	2304
3	20314	18	10234
4	10423	19	01234
5	4013	20	21034
6	42103	21	3401
7	4301	22	34102
8	4302	23	4301
9	4320	24	4230
10	4201	25	41023
11	41023	26	40123
12	40213	27	42103
13	2103	28	4201
14	3014	29	34102
15	31024	30	3041
		31	23104

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



Right: The Great Nebula in the Sword of Orion, a seasonal favorite, spreads its rosy arms of ionized hydrogen. Photo by Jack and Carla Gibbons, who win this month's "Best Astro-Photo" award. They used a 12½-inch telescope and a 30-minute exposure at f/5 on hypered Fuji 400. Left: A solar prominence that occurred on September 16, 1981 as viewed in Hα light. Photo by John Hicks.

record how its appearance changes over the coming weeks. You'll find it easier if you use the same eyepiece for all your sketches, and if you observe while the sky still holds some light to prevent the extreme contrast between Venus and the sky from dazzling you.

Earth

The solstice comes at 16:24 UT on the 21st. This marks the Sun's most southerly declination and the commencement of winter for the northern hemisphere. Winter will last 88 days, 23 hours, and 50 minutes, ending at 16:14 UT on March 20th.

Mars

Will Mars *ever* be caught by the Sun? If you observe at the same time each night (relative to sunset), you find that Mars' visibility in the southwestern evening sky actually increases slightly during December. It is climbing northward along the ecliptic and this keeps it away from the Sun. Despite this, Mars' tiny disk — a bare 5.8″ across on the 15th — offers very little to telescope users beyond the satisfaction of locating it. You'll see a 0.9 magnitude tawny-orange dot of light, perhaps with a hint of dusky markings, but nothing else.

Asteroids

1 Ceres (magnitude 7.5) is a month past opposition and moving retrograde in northeastern Cetus, near the star Menkar in the Whale's tail. Its positions:

10th: 2h 49m 13s, 9° 8.3′
20th: 2h 44m 27s, 9° 35.8′

Ceres sets around 4 a.m. local time on the 15th.

2 Pallas (9.8) is moving due east in central Aquarius. Its positions:

10th: 22h 43m 29s, −10° 46.4′
20th: 22h 52m 16s, −10° 47.1′

Pallas sets about 9:30 p.m. local time on the 15th.

3 Juno (10.5) is moving southeastward in central Virgo. Its positions:

10th: 12h 18m 51s, −3° 18.7′
20th: 12h 28m 46s, −3° 55.5′

Juno rises around 1:30 a.m. local time at mid-month.

4 Vesta (7.9) is in north-central Virgo and heading southeast. Its positions:

10th: 12h 57m 33s, 0° 17.8′
20th: 13h 12m 48s, −0° 50.8′

Vesta rises around 2 a.m. local time on the 15th.

For convenience in plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

During the first week or two of December, you can see Jupiter low in the southwest right after sunset. It lies to the lower right of Venus, and is over two magnitudes fainter. By the end of the month, Jupiter will set around the same time as the Sun — which puts it out of view for telescope observers. Conjunction with the Sun comes on January 14th.

Saturn

Saturn is in the morning sky, in Libra, a few degrees to the southwest of fourth-magnitude Gamma (γ). The rings are tilted about 23° toward our line of sight and, if the atmospheric seeing is settled, moderate powers on small telescopes should reveal the dark Cassini Division between the A and B rings.

The same telescope will also show an eighth-magnitude point of light next to Saturn. This is Titan — the largest of Saturn's moons. It orbits Saturn counterclockwise (as it appears to us) once every 15d 22h 41m. Titan reaches eastern elongation on December 1st (12:30 UT) and 17th (13:00 UT); western elongations occur on the 13th (16:06 UT) and the 29th (16:36 UT).

Uranus

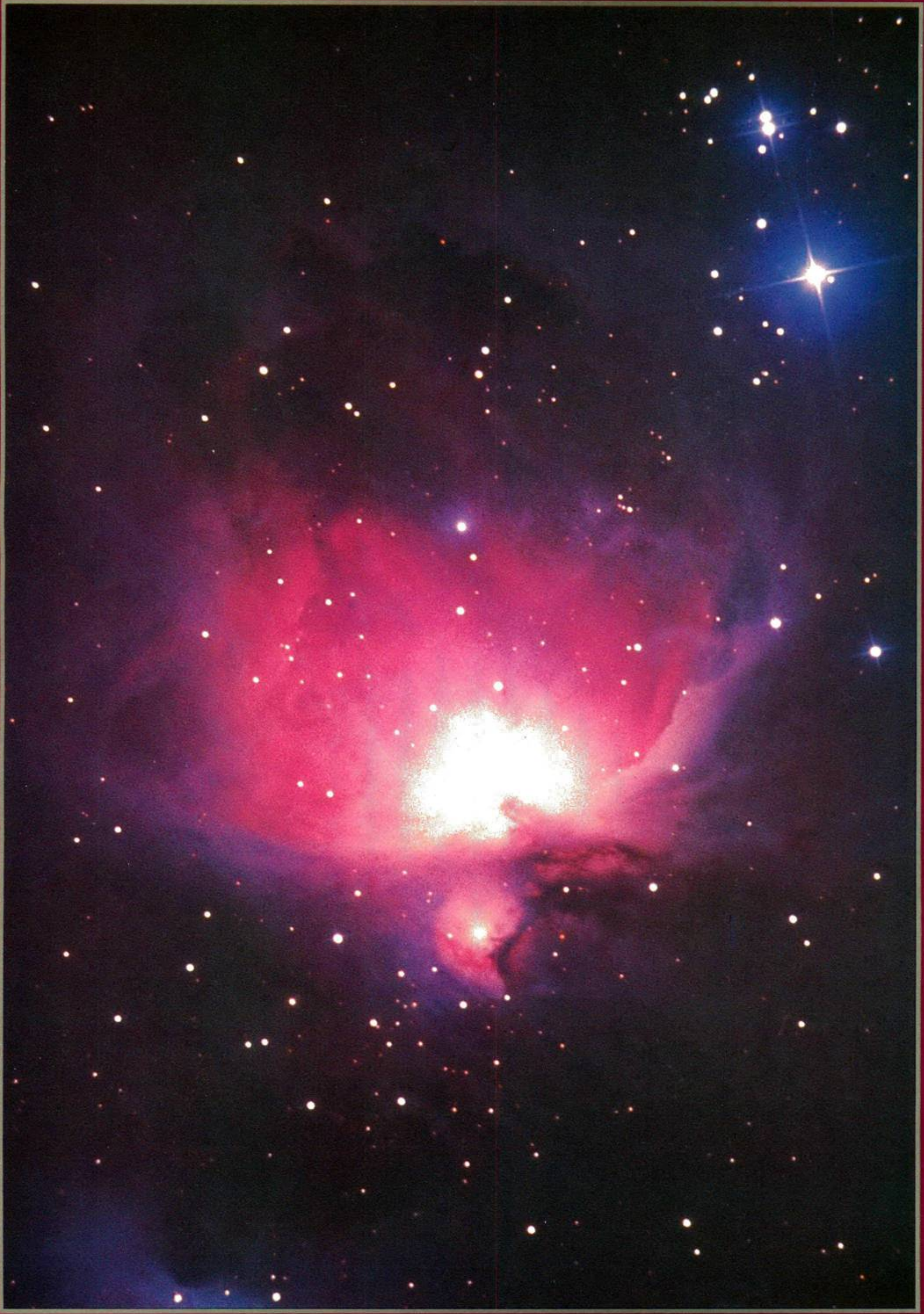
In the last half of December, Uranus rises in the east before the Sun at about the same time as Mercury. The two have conjunctions on the 23rd and 26th, when Mercury passes 3° north of Uranus, but with a separation this wide, you won't be able to frame them together easily in the same telescopic field of view.

Neptune

Neptune is in conjunction with the Sun on the 22nd; it will be out of view until next month.

Meteors

The Geminid shower on the 14th is normally December's most plentiful meteor display. But this year, the shower will be weakened greatly by the Last Quarter Moon, whose light will wash out all but the brightest meteors. Instead, concentrate on the Ursid shower, which reaches peak activity in the early morning hours of the 22nd. The rather idealized zenithal hourly rate for this shower is 10 — rather sparse — but the radiant lies near Beta Ursae Minoris and is visible all night long.



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